Development of a national strategy for adaptation to climate change adverse impacts in Cyprus

CYPADAPT

LIFE10 ENV/CY/000723

Report on the climate change impact, vulnerability and adaptation assessment for the case of Cyprus

DELIVERABLE 1.2

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1 INTRODUCTION

This report constitutes the second Deliverable of Action 1 of the CYPADAPT project on the "Development of a national strategy for adaptation to climate change adverse impacts in Cyprus". Its purpose is to perform a climate change impact, vulnerability and adaptation (IVA) assessment for the case of Cyprus. The methodology followed is structured upon the observed or expected climate change impacts in Cyprus as well as in the wider Mediterannean region and further elaborates on each impact. It must be noted that the IVA carried out in the framework of this report refers to the current situation in Cyprus and it does not take into account projections of climate change impacts in the future. The future IVA assessment for Cyprus is foreseen to take place in the framework of Action 3 of the project.

The selection of the policy areas that have been taken into consideration in the IVA assessment where based on the categorization of policy areas for integrating adaptation, as these were identified in the European Comission's White Paper entitled "Adapting to climate change: Towards a European framework for action". These policy areas where further categorized according to the specific characteristics of Cyprus, as illustrated in the following figure.

Figure 1-1: Selected policy areas in Cyprus for the IVA assessment

Following, one sub-report has been elaborated for each of the sectors presented in the figure above (11 sub-reports in total), based on a common methodology structured upon 3 basic steps:

- **Step 1:** Recording of the baseline situation (current resources, measures and plans for their management, importance of each sector for the country, pressures). This step is very important, as the data gathered were necessary for the assessment of vulnerability, carried out in step 3 of the process.

- **Step 2:** Impact assessment. In this step, a literature review has been made on the observed and expected impacts of climate changes worldwide and especially to the wider area where Cyprus is located. The impacts for the case of Cyprus were identified and relevant data were presented where available. Following, the trends of the observed impacts and the likelihood of the expected impacts were evaluated.

- **Step 3:** Vulnerability assessment. In this step, the vulnerability of each of the identified impacts was assessed in terms of sensitivity, exposure and adaptive capacity of the sector to climate changes, based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which a system is affected by climate changes, exposure is the degree to which a system is exposed to climate changes and their impacts while the adaptive capacity is defined by the ability of a system to adapt to changing environmental conditions. Adaptive capacity is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

  For the vulnerability assessment various criteria were used, such as the magnitude, timing, distribution, persistence and reversibility of impacts as well as other social criteria. The assessment of overall vulnerability was based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

  The general concept of the methodology followed was adopted by the "Impacts, Adaptation and Vulnerability" Assessment Reports of the Intergornmental Panel on Climate Change, while the assessment was further elaborated by the CYPADAPT team in order to prioritize the impacts of all sectors and identify the key vulnerabilities for Cyprus. For this to be achieved, sensitivity, exposure and adaptive capacity were evaluated with the use of a qualitative 7-degree scale ranging from "none" to "very high". The key vulnerabilities have been identified as those impacts gathering an overall vulnerability score ranging from "moderate" to "very high".

Overall, 52 climate change impacts have been identified in the selected policy areas of Cyprus, from which 16 have been evaluated as key priorities for adaptation action. In Table 1-1, the identified impacts in Cyprus as well as the key priorities are presented, while in Annex I, the scores of sensitivity, exposure, adaptive capacity and vulnerability for each impact are presented.

Table 1-1: Impacts of climate change in the selected policy areas of Cyprus

Sector	Impacts	Key vulnerabilities	Prioritization
Water resources	Water availability for domestic water supply	☆	(6)
	Water availability for irrigation	☆	(1)
	Surface water quality		
	Groundwater quality	☆	(2)
	Droughts	☆	(1)
	Floods		
Agriculture	Crop yield	☆	(3)
	Soil fertility		
	Pests and diseases*		
	Damages to crops from extreme wheather events	☆	(5)
	Livestock productivity*		
	Costs for livestock catering *		
Forests	Dieback of tree species, insect attacks and diseases	☆	(2)
	Fires	☆	(4)
	Forest growth*		
	Floods		
Fisheries and aquaculture	Quantity and diversity of fishstocks*		
	Fishstock physical environment*		
	Costs implications for fishermen*		
Coastal zones	Coastal erosion	☆	(5)
	Coastal storm flooding and inundation		
	Degradation of coastal ecosystems *		
Biodiversity	Distribution of plant species in terrestrial ecosystems	☆	(4)
	Distribution of animal species in terrestrial ecosystems	☆	(4)
	Freshwater biodiversity		
	Marine biodiversity		
Soils	Soil erosion (by wind and/or rain water)	☆	(5)
	Soil salinization – Sodification		
	Soil contamination		
	Desertification	☆	(1)

Sector	Impacts	Key vulnerabilities	Prioritization
	Landslides		
Energy	Energy demand for cooling and heating		
	Renewable energy yield (other than hydropower)		
	Efficiency of thermal power stations		
Infrastructure	Damages to infrastructure due to urban floods		
	Damages to infrastructure due to sea floods		
	Damages to infrastructure due to landslides *		
Tourism	Warmer summers	☆	(4)
	Warmer winters		
	Coastal erosion		
	Water availability	☆	(6)
	Heat waves		
	Biodiversity attractions		
	Storms, waves and floods		
Public health	Deaths and health problems related to heat waves and high temperatures	☆	(5)
	Vector and rodent-borne diseases		
	Water- and food-borne diseases		
	Deaths, injuries and diseases from floods/storms		
	Air pollution-related diseases		
	Fire- related deaths and injuries		
	Climate-related effects upon nutrition		
	Landslide-related deaths and injuries		

* In absence of sufficient data for the evaluation of sensitivity and/or exposure, the overall vulnerability of this impact was not evaluated

However, it must be noted that, there were no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. For that reason, a preliminary assessment of the vulnerability of Cyprus was made while where knowledge and research gaps were identified, suggestions were made for further research.

2 NATURAL & HUMAN ENVIRONMENT

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This section provides comprehensive data on the natural and human environment of Cyprus. This information will help the reader to get acquaintance with modern Cyprus in general as well as with the existing strengths and weaknesses of the island associated with climate change adaptation and vulnerabilities.

Before presenting this information, it was considered of particular importance to notice that Cyprus enjoys its freedom from British colonial rule since 1960 and that 34% of its sovereign territory is occupied since 1974 when Turkey invaded the island. The “ceasefire line” runs right across the island and cuts through the heart of Lefkosia (Nicosia), the capital of the country. It is noted that even though the Republic of Cyprus is recognized as the sole legitimate state of the island, the information regarding Cyprus presented in this report refer to the areas of the island which are under the control of the Republic of Cyprus (excluding the northern part of the island that is occupied by Turkey, unless otherwise stated).

Cyprus is an independent sovereign Republic with a presidential system of government. Cyprus joined the European Union on 1 May 2004 while adopted the Euro in 2008. Cyprus takes over the Presidency of the Council of the European Union from July to December 2012.

“Ceasefire line” of Cyprus: Turkish occupied territory (orange), Greek part of Republic of Cyprus, British sovereign bases

Cyprus flag

Figure 2-1: Ceasefire line of Cyprus (on the left) and Cyprus flag (on the right)

2.1 Natural Environment

2.1.1 Geographical position

Cyprus is the third largest Island of the Mediterranean sea after Sicily and Sardinia with a total area of 9,251 sq km (3,572 sq miles), extending 240 km (149 miles) from east to west and 100 km (62 miles) from north to south. It is strategically situated in the extreme northeastern corner of the Mediterranean (33° E, 35° N), at the crossroads of Europe, Africa and Asia (see also Figure 2-2), bordering Egypt 300 km to the South, Syria 105 km to the East and Turkey 71 km to the North.

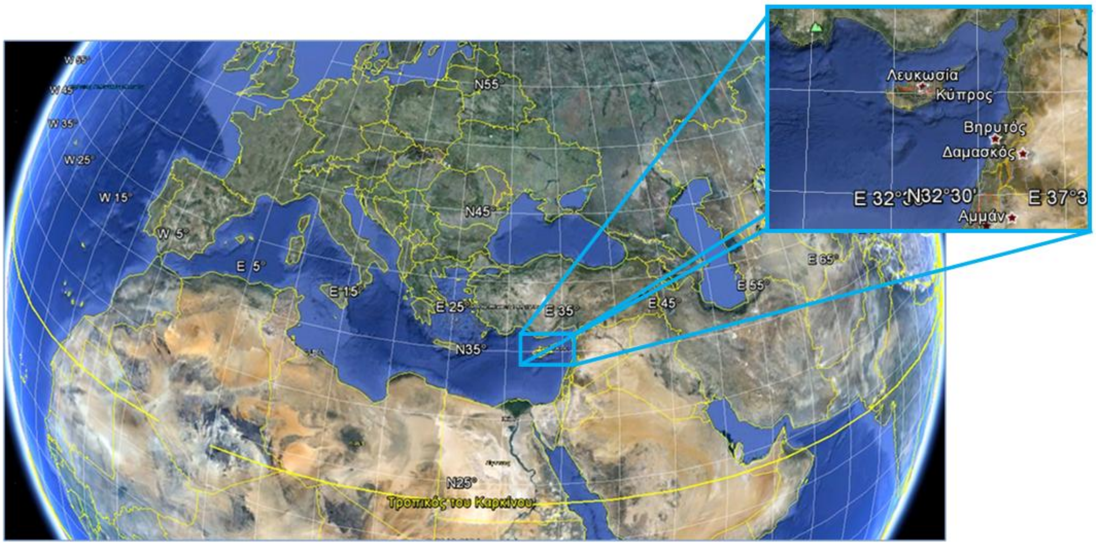


Figure 2-2: Location of Cyprus

2.1.2 Topography and geology

Topography

Cyprus consists of a central fertile plain (plain of Messaoria) and two mountain ranges: the Troodos Mountains and the Pentadaktylos range which runs along almost the entire northern coast. As illustrated in Figure 2-4 the latter comprises just a minor coastal range compared to the Troodos massif in the central and south-western parts of the island which culminates in the peak of Mount Olympus, 1,953 m above sea level.

Snow is quite frequent in the peaks of Troodos mountains, the melting of which along with the low rainfall provide the island's 100 dams with the necessary amounts of water for satisfying the water needs of Cyprus. There are 14 main rivers in Cyprus all of which originate in the Troodos mountain. The largest river of Cyprus is Pediaios (length: 100km). All rivers dry up during summer. Cyprus' coastal line is indented and rocky in the north with long sandy beaches in the south.

Geology

The island is divided into four geological zones: (a) the Pentadaktylos (Kyrenia) Zone (b) the Troodos Zone or Troodos Ophiolite (c) the Mamonia Zone or Complex and (d) the Zone of the autochthonous sedimentary rocks.

Figure 2-3: Geology zones of Cyprus

Source: Adapted from http://www.moa.gov.cy

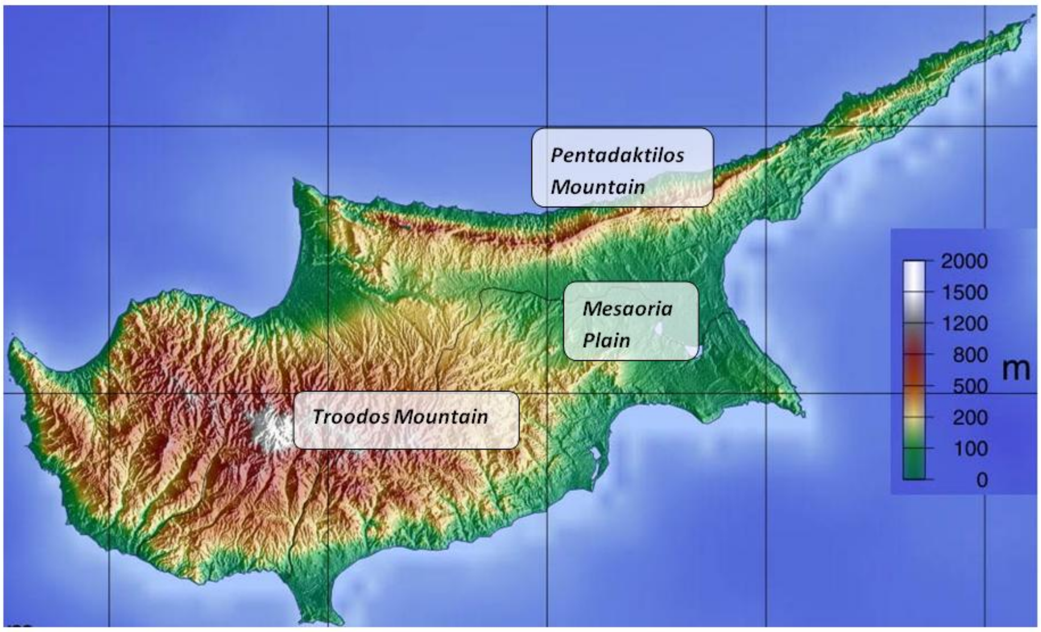


Figure 2-4: Geophysical map of Cyprus

2.1.3 Climate profile

Cyprus has a Mediterranean climate with hot dry summers (duration: June to September) and mild, wet winters (duration: November to March), which are separated by short Autumn and Spring seasons of rapid change in weather patterns in October, April and May. Sunshine is abundant during the whole year. The daylength varies from 9.8 hours in December to 14.5 hours in June while the daily average sunshine exceeds eleven hours.

2.1.4 Land uses

The agricultural areas have the biggest share accounting for 47.92% of the total area of Cyprus, followed by the forest and semi-natural areas with a share of 43.19%. The aggregate share of these two sectors surpasses 90% of the total area, leaving small share for the other categories: 8.45% for artificial areas and 0.44% for water courses and water bodies (see Figure 2-5). A more detailed breakdown of land uses per category, as indicated by the Corine Land Use classification system is given in Table 2-1, while an analytical map representation is given in Figure 2-6.

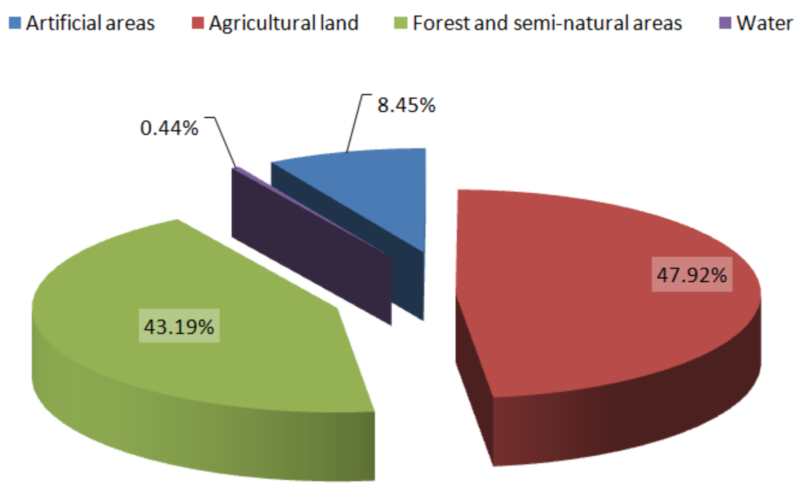


Figure 2-5: Level 1 Classes of CLC2006 in Cyprus

Source: DoA, 2011

Table 2-1: Land use cover according to CLC2006 classification

Classification No (CLC 2006)		Land use	CORINE 2006	Land Use Change 2000-2006
			x 1000 m^2	%
Artificial areas	1.1.1.	Continuous urban fabric	565	1
	1.1.2.	Discontinuous urban fabric	48485	11
	1.2.1.	Industrial or commercial units	14230	17
	1.2.2.	Roads and rail networks	542	40
	1.2.3.	Port areas	427	19
	1.2.4.	Airports	2525	1
	1.3.1.	Mineral extraction sites	2553	-16
	1.3.2.	Dump sites	367	22
	1.3.3.	Construction sites	528	-243
	1.4.1.	Green urban areas	1010	-8
	1.4.2.	Sport and leisure facilities	6877	43
Agricultural Areas	2.1.1.	Non-irrigated arable land	238916	-2
	2.1.2.	Permanently irrigated land	18879	-2
	2.2.1.	Vineyards	14117	1
	2.2.2.	Fruit trees and berry plantations	15560	6
	2.2.3.	Olive groves	6530	0
	2.3.1.	Pastures	1167	25
	2.4.1.	Annual and permanent crops	32242	-5
	2.4.2.	Complex cultivation patterns	73223	4
	2.4.3.	Agriculture with natural vegetation	41853	8
	2.4.4.	Broad-leaved forest	723	-6
Forest and semi-natural areas	3.1.2.	Coniferous forest	153568	-1
	3.1.3.	Mixed forest	355	-1
	3.2.1.	Natural grassland	28175	-14
	3.2.3.	Sclerophylous vegetation	157817	-2
	3.2.4.	Transitional woodland/shrub	39577	28
	3.3.1.	Beaches, dunes and sand plains	5145	-2
	3.3.2.	Bare rocks	2536	-13
	3.3.3.	Sparsely vegetated areas	12007	-1
	3.3.4.	Burnt areas	245	-4656
Water	4.2.2	Salt marshes	2488	21
	5.1.	Water bodies	1582	12

Note: the information provided in the last column is referring to the land use change between CLC2000 and CLC2006

Source: DoA, 2011

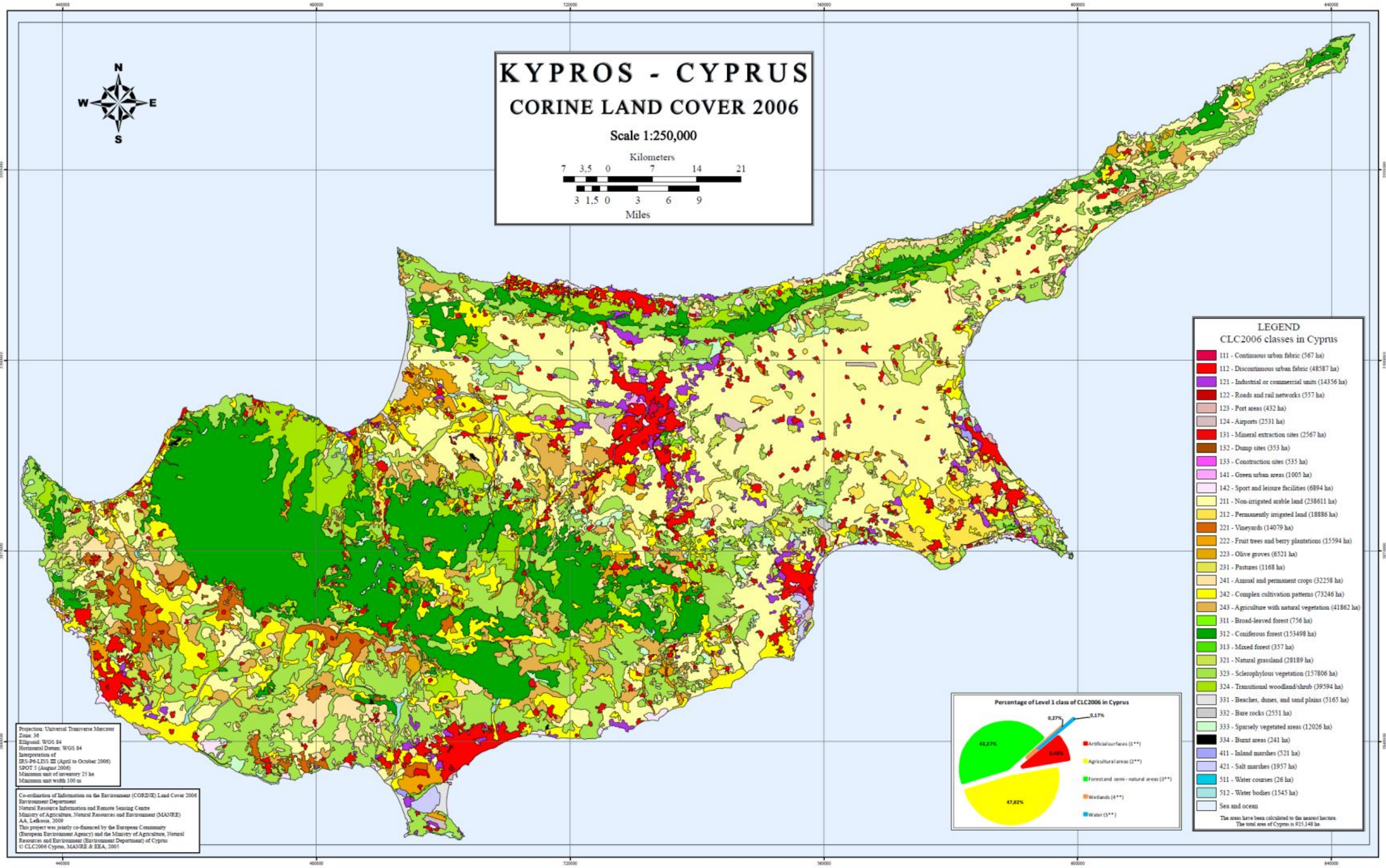


Figure 2-6: Land cover of Cyprus (CORINE presentation, data 2006)

Source: DoA, 2011

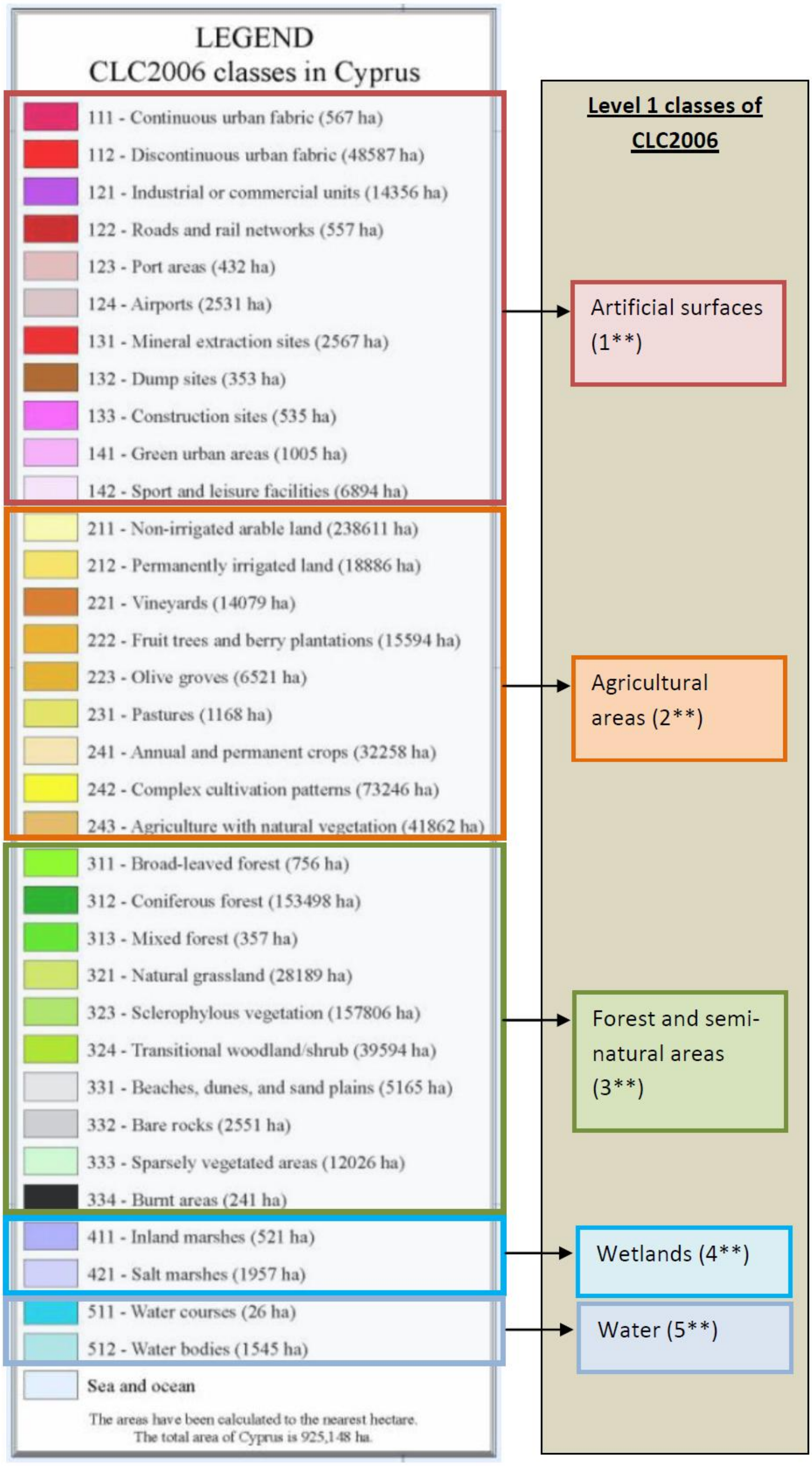


Figure 2-7: Legend of CLC2006 classes in Cyprus

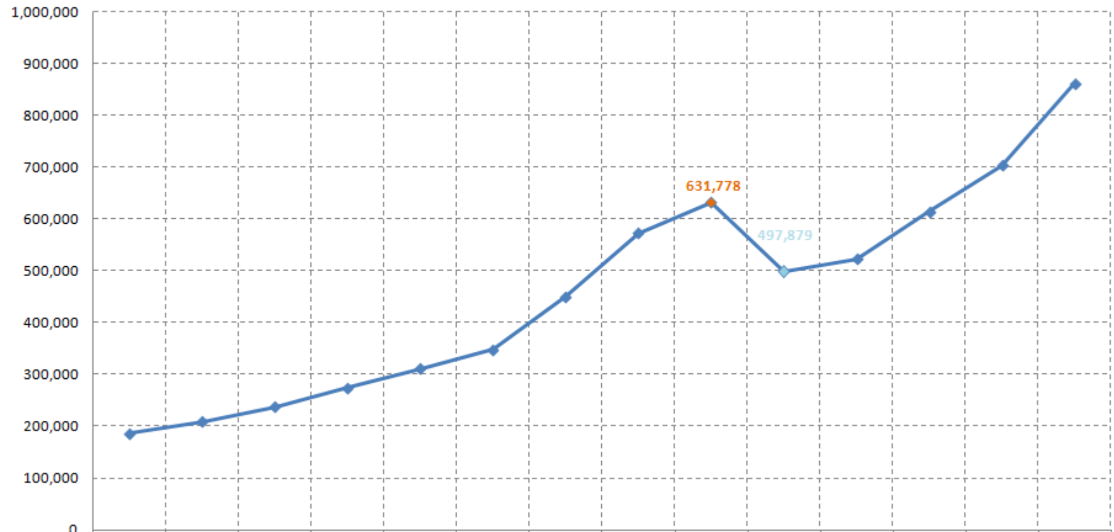
Source: DoA, 2011

2.2 Human environment

2.2.1 Population profile

The population of Cyprus was 862,000 at the end of 2011. The growth of population between 1881 and 2011 is presented in Figure 2-8. It has increased by 363% since 1881. However, it is worth noticing that a remarkable fall of approximately 21% is observed in 1976, when the last Census after the Turkish invasion took place (date of Turkish invasion: 20/07/1974).

Note that this steep decrease of the population was recorded between the Census of 30/09/1976 and the Census of 01/04/1973, meaning that it represents the change of the population between approximately 3.5 years.



	1881	1891	1901	1911	1921	1931	1946	1960	1973	1976	1982	1992	2001	2011
Population	186,173	209,286	237,022	274,108	310,715	347,959	450,114	573,566	631,778	497,879	522,845	615,013	703,529	862,000

Note: (a) The population is referring to the areas of the island which are under the control of the Government of Cyprus. The data for 2011 are referring to December and has been obtained by MoI, 2012

(b) The x axis is not linear

Figure 2-8: Population growth in Cyprus (1881-2010)

Adapted from CYSTAT, 2011a

The population density of the island averages at 103 persons per square kilometer but ranges from less than 10 persons per km^2 to 1000 persons per km^2 in the urban centers of Cyprus. An analytical map of Cyprus with spatial distribution of population density is presented in Figure 2-10. It can be seen that the population density varies significantly across regions of Cyprus and that the population accumulates mostly in the urban centers of the island, the majority of which are located in coastal areas.

According to the latest data of the 2011 Population Consensus, the population by district of Cyprus is as follows:

Districts	Population (December 2011)
Lefkosia (Nicosia)	336,000
Lemesos (Limassol)	241,300
Larnaka (Larnaca)	146,300
Pafos (Paphos)	90,800
Ammochostos (Famagusta)*	47,600
Total	**862,000**

**Government controlled area*

The population is ageing. The proportion of children below 15 years old has decreased (16.9% and 25.4% for 2009 and 1982 respectively), while the proportion of elderly people above 65 years old has increased (13% and 11% for 2009 and 1982 respectively) demonstrating that the median age of the country is rising (CYSTAT, 2011a). According to the Ministry of Interior (MoI, 2012) the life expectancy in Cyprus is 79 years and 82.9 years for males and females respectively (see also Figure 2-9). The ageing of the population has implications both for health & welfare costs as well as for the potential of increased vulnerability associated with this susceptible social group (e.g risk of elderly people to extreme weather events such as heat waves).

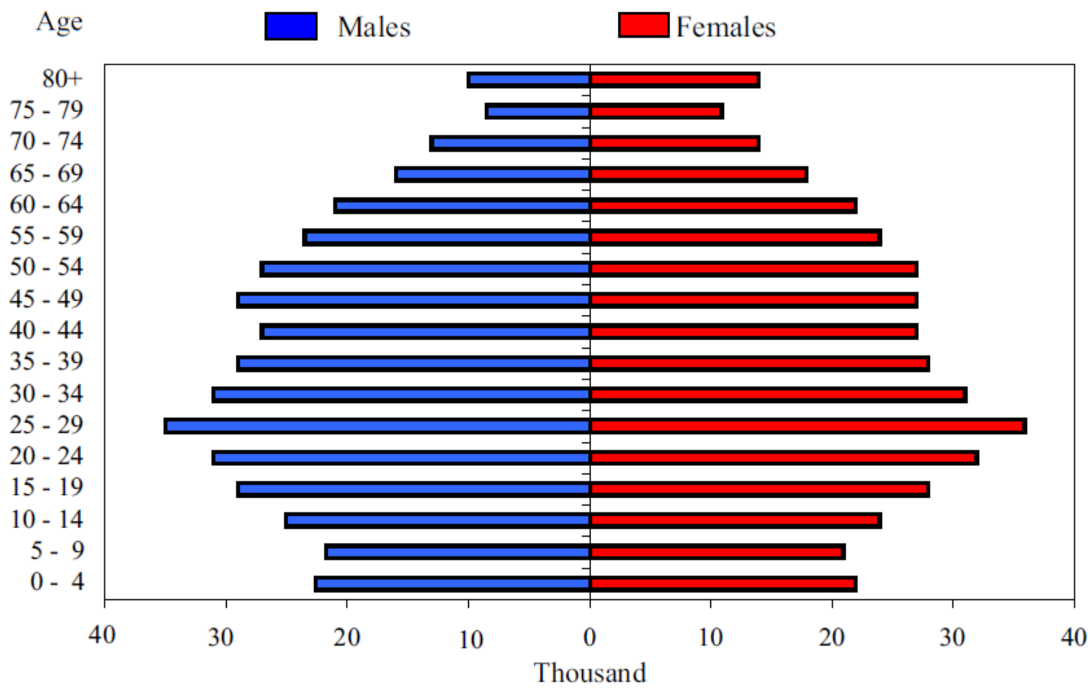


Figure 2-9: Population by age and sex in Cyprus, 2009

Source: CYSTAT, 2011a

Finally, regarding the national composition of the island[1], 71.5% are Greek Cypriots, 9.5% are Turkish Cypriots while 19% are foreign residents, out of which (MoI, 2012):

- 113,300 (13.1%) originate from EU countries; and
- 67,700 (7.85%) originate from non-EU countries.

[1] The percentages refer to the population of the island of Cyprus (952,100) and not only to the Republic of Cyprus

Figure 2-10: Population density of Cyprus Island

Source: stockmapagency.com

2.2.2 Education

All children in Cyprus receive compulsory education between $4^{2}/_{3}$ and 15 years old. The Cypriot educational system comprises the following levels:

- Pre-school and preliminary education (<$5^{2}/_{3}$ years old), *compulsory since 2004 for children aged between $4^{2}/_{3}$ and $5^{2}/_{3}$*;
- Primary education ($5^{2}/_{3}$ < Age < 12), *compulsory since 1962*;
- Secondary education. This level of education comprises two stages, each with three year course duration. *The first stage (Gymnasia) is compulsory since 1985* while the second stage (Lyceums) of education is optional and the students can choose among public, private, technical and vocational Lyceums.
- Tertiary education, *not compulsory*.

In the following table some critical education indicators are provided for Cyprus and EU27.

Table 2-2: Comparison of education indicators between Cyprus and EU27

Item	Cyprus	EU27
Percentage of young people in the ages 20-24 with highest educational attainment at least upper Secondary level	86.30%	79.00%
Percentage of the population aged 25-64 having completed at least Upper Secondary level, 2010	74.10%	72.70%
Early leavers from education and training, 2010	12.60%	14.10%
Percentage of people between ages 25-64 with tertiary education qualifications, 2010	35.60%	25.90%
Percentage of people between 30-34 with tertiary education qualifications, 2010	45.10%	33.60%
Lifelong Learning	7.70%	9.10%
Percentage of students studying in another EU-25, EEA or Candidate country, 2009	36.40%	2.70%
Public expenditure on education as a percentage of GDP, 2008	7.40%	5.10%

Adapted from CYSTAT, 2012a

As illustrated in Table 2-2, the figures of the critical education indicators reveal that the vast majority of the Cypriot population is well educated and it scores higher in most of them comparing to EU27. As education contributes significantly to the receptiveness of new ideas and challenges as climate change adaptation, the high level of education of the Cypriot population implies that awareness building shall require reduced effort. This is of particular importance when addressing the matter of adaptive capacity to climate change induced impacts, the vulnerability of which is strongly dependent on human behavior and response (e.g. for the health sector when addressing the matter of reducing vector-borne diseases).

2.2.3 Employment

The employed persons has increased by approximately 0.19% from 2009 to 2010 (375,400 and 376,100 employed persons respectively). The breakdown of employed persons is presented in Table 2-3 by economic activity for 2010.

Table 2-3: Employed persons by economic activity in Cyprus (2010 data)

NACE Code (Rev. 2)	Economic Activity	Employed persons (thousands)	Share
A.	Agriculture, Forestry and Fishing	27.9	7.37%
B.	Mining and Quarring	0.7	0.18%
C.	Manufacturing	33.8	8.92%
D.	Electricity, Gas, Steam and Air Conditioning Supply	1.6	0.42%
E.	Water Supply; Sewerage, Waste Management and Remediation Activities	2.3	0.61%
F.	Construction	36.3	9.58%
G.	Wholesale and Retail Trade, Repair of Motor Vehicles and Motorcycles	66.4	17.53%
H.	Transportation and Storage	16.9	4.46%
I.	Accommodation and Food Service Activities	34.6	9.13%
J.	Information and Communication	8.8	2.32%
K.	Financial and Insurance Activities	17.6	4.65%
L.	Real Estate Activities	1.5	0.40%
M.	Professional Scientific and Technical Activities	16.4	4.33%
N.	Administrative and Support Service Activities	6.1	1.61%
O.	Public Administration and Defence; Compulsory Social Security	29.0	7.66%
P.	Education	22.4	5.91%
Q.	Human Health and Social Work Activities	15.3	4.04%
R.	Arts, Entertainment and Recreation	4.8	1.27%
S.	Other Service Activities	8.9	2.35%

NACE Code (Rev. 2)	Economic Activity	Employed persons (thousands)	Share
T.	Activities of Households as employers	24.8	6.55%
U.	Activities of Extra-territorial Organizations and Bodies	2.7	0.71%
Total		378.8	100%

Adapted from CYSTAT, 2011b

The structure of employment for the three broad sectors, namely primary, secondary and tertiary sector, is presented in the following figure.

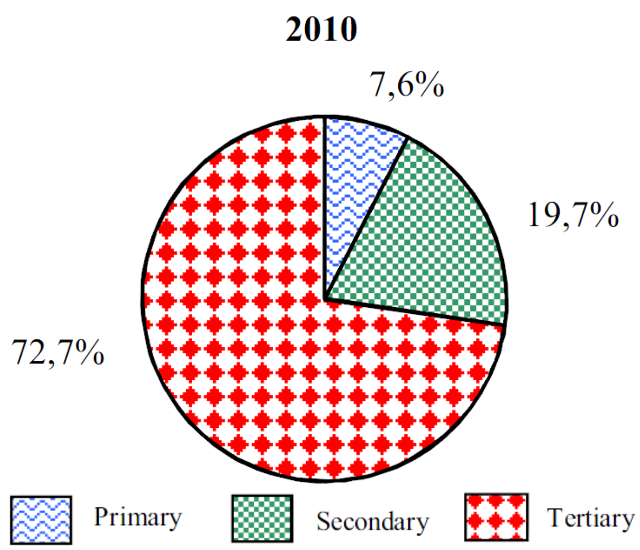


Figure 2-11: Structure of employment in broad sectors (2010 data)

Source: CYSTAT, 2012b

In 2010, the unemployed persons totaled 25,372 which correspond to an increase of approximately 19% compared to 2009 levels (21,325 persons). The share of unemployed persons in the total economically active population is estimated at 6.2% in 2010 (25,372 unemployed over 412,600 economically active persons), while the corresponding share for 2009 was 5.3% (21,325 unemployed over 407,700 economically active persons).

It is noted that the newcomers in the labour force account for 16% of the total number of unemployed in 2010, meaning that 4,070 out of 25,372 unemployed were persons that had never worked in the past and were looking for work for the first time. Trade, restaurant and hotels comprise the economic activity with the largest difference in unemployment rate as illustrated in Figure 2-12.

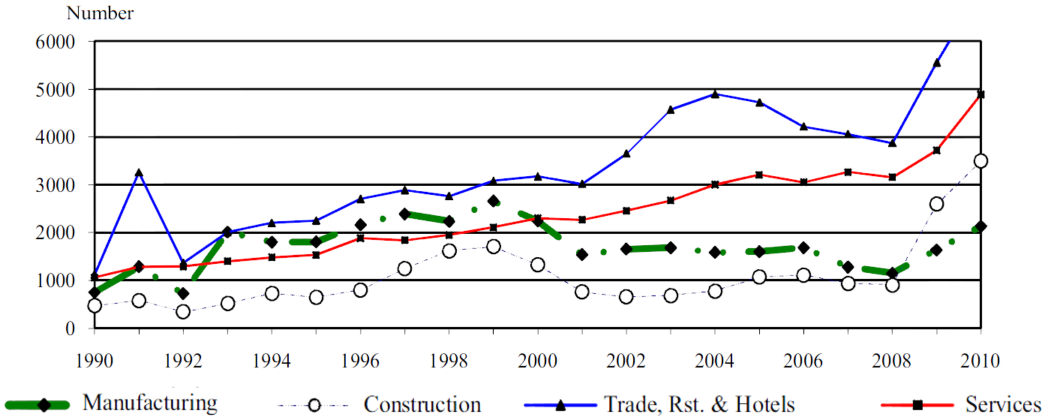


Figure 2-12: Unemployment by economic activity

Source: CYSTAT, 2012b

2.2.4 Gross Domestic Product (GDP)

On 1 May 2004 Cyprus became member of the European Union, while adopted Euro as its national currency in 2008. During the last two decades, the economy of Cyprus has turned to services and light manufacturing. The change of Gross Domestic product over the last 15 years is presented in Figure 2-15 while comparison of the per capita Gross Domestic Product (GDP) of Cyprus with the other EU members is given in Figure 2-14.

Finally the share of GDP by economic sector and their change over time since 1995 are given in Figure 2-15 and Figure 2-16 respectively.

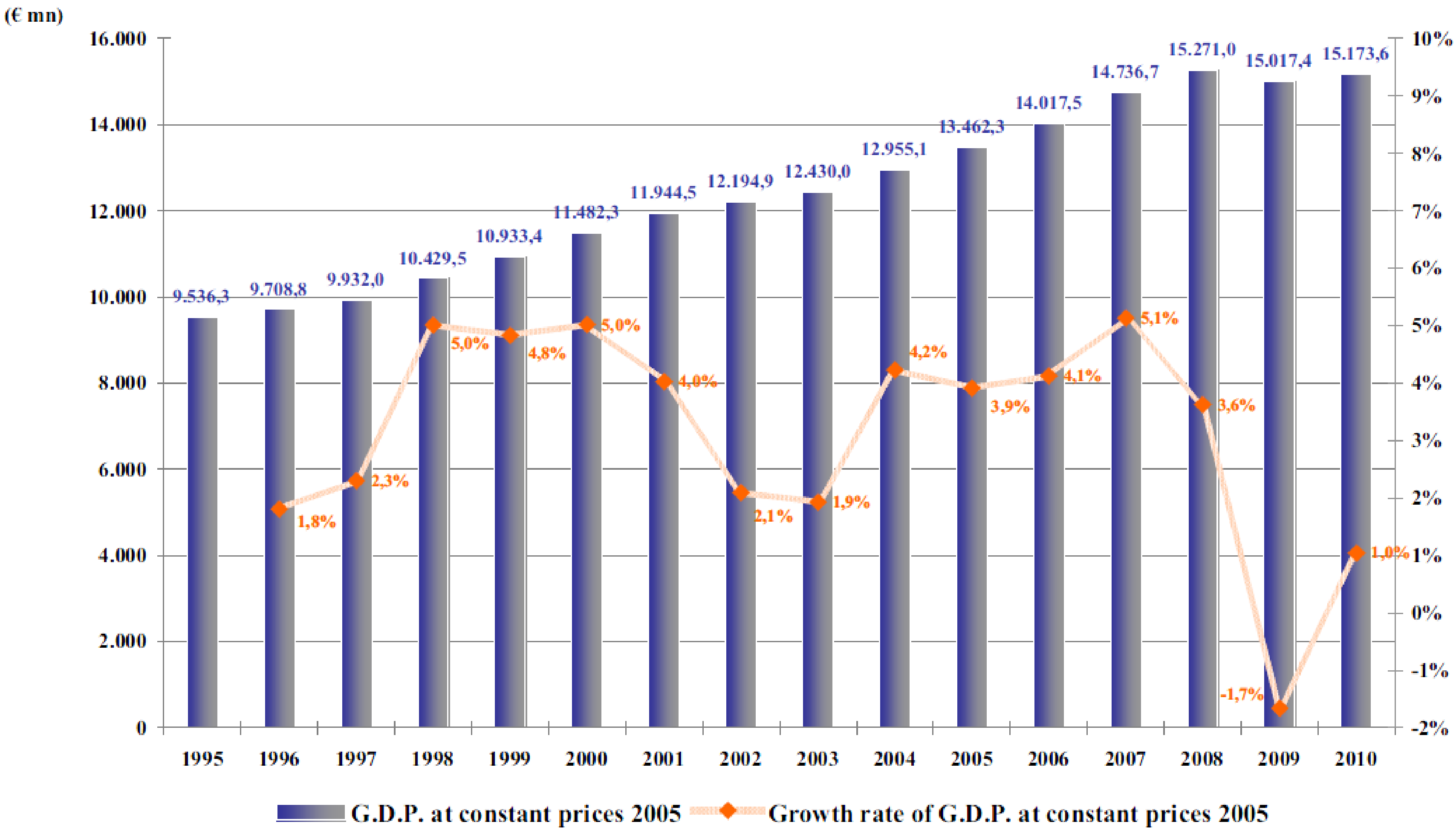


Figure 2-13: Gross Domestic Product at constant prices 2005 (left-hand scale) and annual change of GDP (right-hand scale)

Source: CYSTAT, 2011b

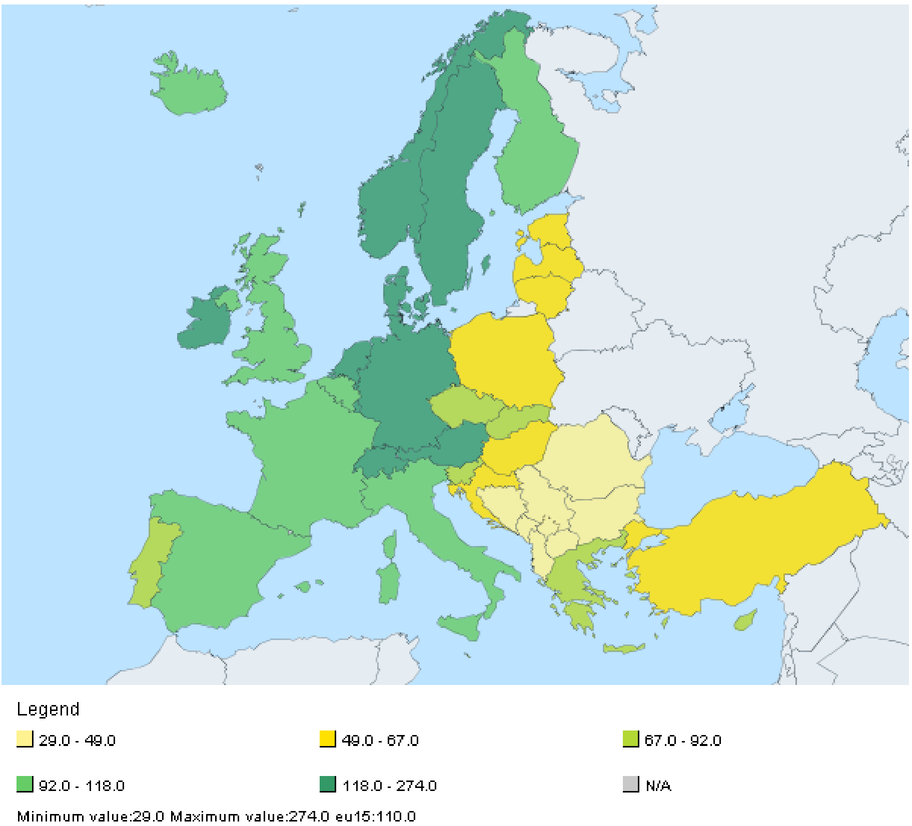


Figure 2-14: GDP per capita in PPS (Index EU27=100) – 2011

Source: Eurostat

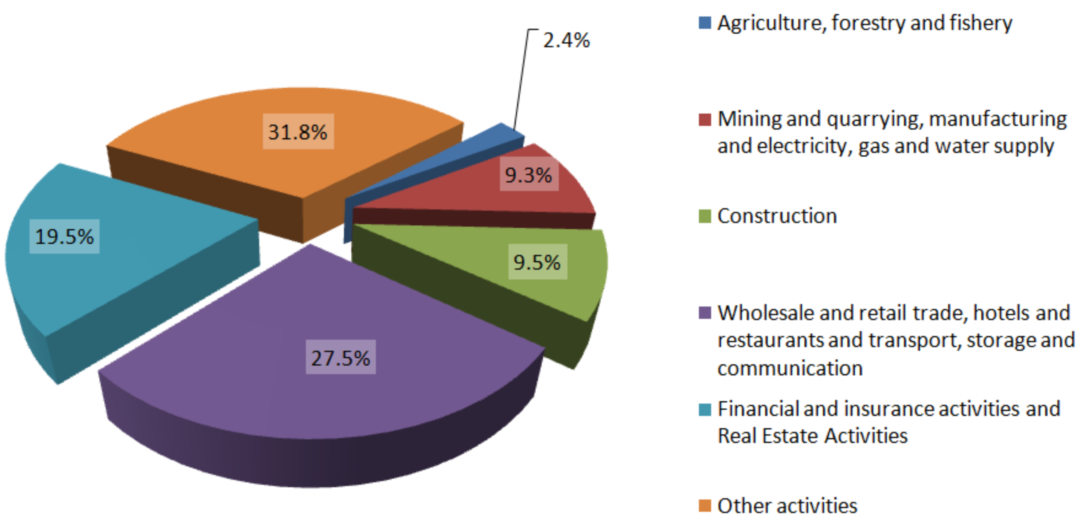


Figure 2-15: Distribution of Gross Domestic Product by economic activity (Current market prices) - 2010

Source: Adapted from CYSTAT, 2011b

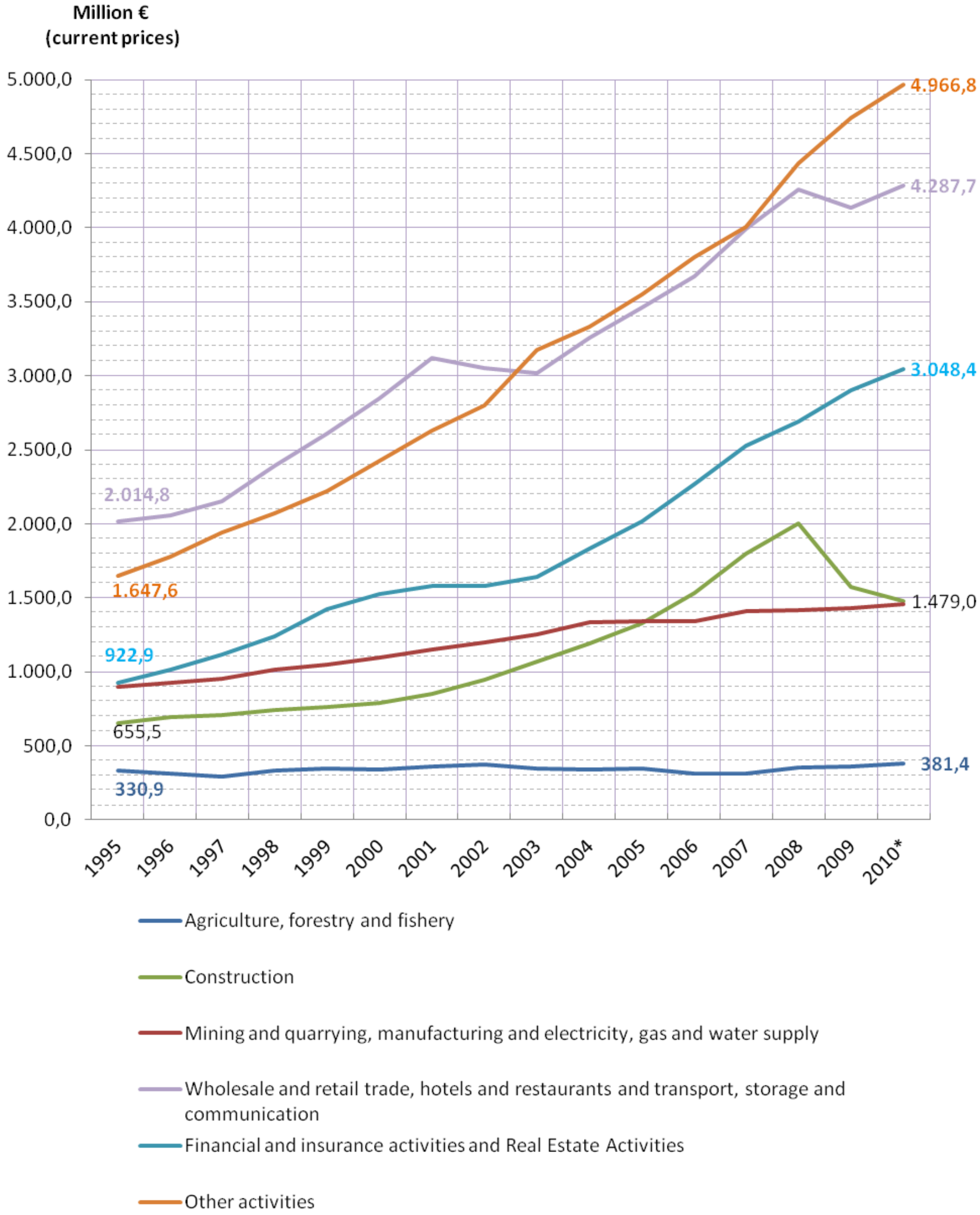


Figure 2-16: Gross domestic product growth by economic activity (1995-2010)

Source: CYSTAT, 2011b

2.3 References

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3 WATER RESOURCES

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Abbreviations and Acronyms

AR4	Fourth Assessment Report
DISMED	Desertification Information System to Support National Action Programmes in the Mediterranean
DMP	Drought Management Plan
EC	European Commission
EEA	European Environment Agency
ESA	Environmentally Sensitive Areas
FAO	Food and Agriculture Organization
FVI	Flow Variability Index
GSD	Geological Survey Department
ICOLD	International Commission of Large Dams
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
MANRE	Ministry of Agriculture, Natural Resources and Environment, Republic of Cyprus
MSC	Meteorological Service of Cyprus
SDI	Sensitivity to Desertification Index
SPI	Standardized Precipitation Index
SUDS	Sustainable Urban Drainage Systems
SWV	Surface Water Vulnerability
VNZ	Vulnerable Nitrate Zones
WAI	Water Availability Index
WDD	Water Development Department
WEI	Water Exploitation Index
WFD	Water Framework Directive
WSI	Water Stress Index

3.1 Climate change and water resources

Water resources are closely interrelated with climate as the water cycle depends on climate factors. More specific, water is received through precipitation while a large part is evaporated directly or is returned to the atmosphere via plants (transpiration). Evapotranspiration is strongly dependant on climatic factors such as temperature, radiation, vapor pressure and wind. In addition, higher temperatures increase water-holding capacity of the atmosphere and evaporation, resulting in increased climate variability, with more intense precipitation and more droughts (Trenberth et al., 2003).

Climate changes such as increases in temperature, sea level and precipitation variability affect freshwater systems and their management (Kundzewicz et al., 2007) with a potential of high vulnerability not only for water resources but also to human societies and ecosystems as a concequence (Bates et al., 2008).

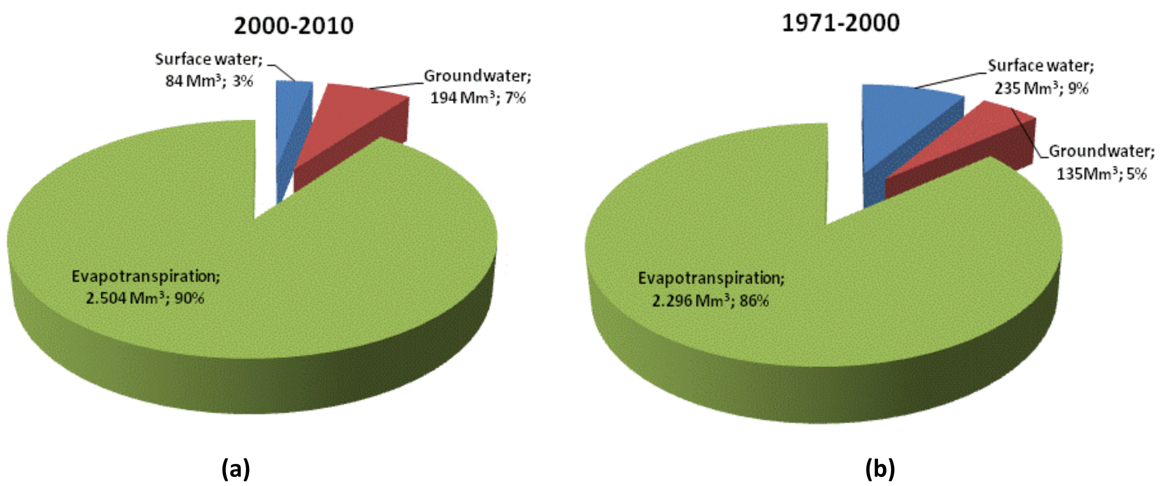
The water resources of Cyprus are considered vulnerable to climate changes, since they are limited due to the semi-arid climate that characterizes the island. Freshwater availability depends almost entirely on rainfall which is highly variable with frequent prolonged periods of drought. As a result, water demand for various uses exceeds in most cases the amount of freshwater available. In order to satisfy the demand for domestic water supply as well as the demand from other water users (agriculture, tourism, industry, livestock) and to protect ecosystems, a large number of measures has been undertaken so far in Cyprus. Although water availability has substantially increased, the pressure on water resources remains obvious.

3.2 Baseline situation

For the year 2010, the available natural water resources of Cyprus in the areas under Government control amounted to 197 Mm^3 (or 429 m^3/capita), made up from 119 Mm^3 surface water and 78 Mm^3 from groundwater resources. Another 65 Mm^3 were available from non freshwater resources; 53 Mm^3 from desalination of seawater and 12 Mm^3 from treated domestic effluents (WDD[2]).

3.2.1 Hydrology

The main natural source of water in Cyprus is rainfall. The average quantity of water falling over the total surface area of the free part of Cyprus for the period 2000 - 2010 is estimated to be 2.783 Mm^3, but the actual inflow is only 10% or 278 Mm^3, since the remaining 90% returns to the atmosphere as direct evaporation and transpiration. The average annual net rainfall is distributed between surface and groundwater storage with a ratio of approximately 1:2. The situation is different from that prevailing during the period 1971 – 2000 where surface water inflow was approximately 1.7 times higher than groundwater inflow. Figure 3-1 shows the quantity and distribution of freshwater resources in Cyprus for the periods 2000 -2010 and 1971-2000.



(a) FAO, 2000
(b) Prossessed data provided by the WDD

Figure 3-1: Relation between evaporation, surface and groundwater flow of precipitated water (WDD) for the period 2000-2010 and 1971-2000

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

3.2.1.1 Precipitation

Until 1997 the main source of water in Cyprus was rainfall. According to a long series of observations, the mean annual precipitation for the period 1960-1990 was estimated at 503 mm, and from 2000 until now has been reduced to 468 mm. The rainfall is unevenly distributed geographically with the highest in the two mountain ranges and the lowest in the eastern lowlands and coastal areas. Additionally there is great fluctuation in rainfall with frequent droughts spanning two to four years.

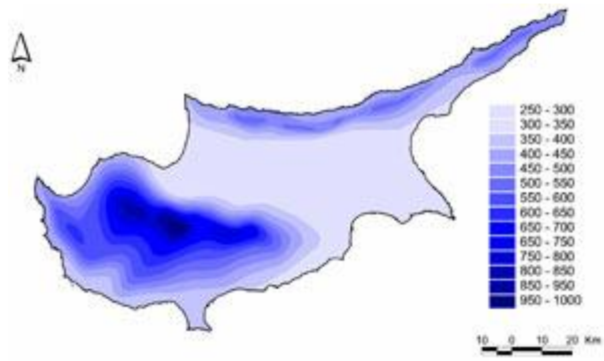


Figure 3-2: Spatial distribution of rainfall in Cyprus

Source: WDD (1)

3.2.1.2 Surface runoff – evapotranspiration

The seasonal distribution of surface runoff follows the seasonal distribution of precipitation, with minimum values during the summer months and maximum values during the winter months. As a result of the Eastern Mediterranean climate with long hot summers and a low mean annual precipitation, there are no rivers with perennial flow along their entire length. Most rivers flow 3 to 4 months a year and are dry during the rest of the year. Only parts of some rivers upstream in the Troodos areas have a continuous flow (rivers of Xeros, Diarizos, Kargotis, Marathasa, Kouris and Germasogeia). 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 (WDD (1)).

It is considered that 85 – 90% of rainfall returns to the atmosphere as evapotranspiration, which may reach 95% for dryer years. Therefore, the variability of rainfall is reinforced from the increase of the losses to atmosphere, as the rainfall decreases. The need to decouple drinking water supply and irrigation from annual rainfall variability led to the exploitation of groundwater aquifers in which accumulated flows (> 1 year) are stored and in the subsequent construction of dams of long-term storage.

3.2.1.3 Groundwater flow

Based on the data for the period 2000 – 2010, it is estimated that the natural recharge of the groundwater bodies under the effective control of the Republic of Cyprus is 194 Mm^3 annualy. Groundwater bodies are also artificially recharged with water from dams and recycled water.

3.2.1.4 Water demand

The total annual water consumption for 2011 was estimated to be 258 Mm^3. The two major water consumers are the agriculture sector (irrigation) and the domestic sector, with a consumption of 60% and 30%, respectively. The amount of water demand for irrigation is met by approximately 70% water from Government Water Works and 30% water from private boreholes (legal and illegal). Domestic sector includes water consumption for permanent population (26%) as well as for tourism purposes (4%) (WDD, 2011a - Annex VII).

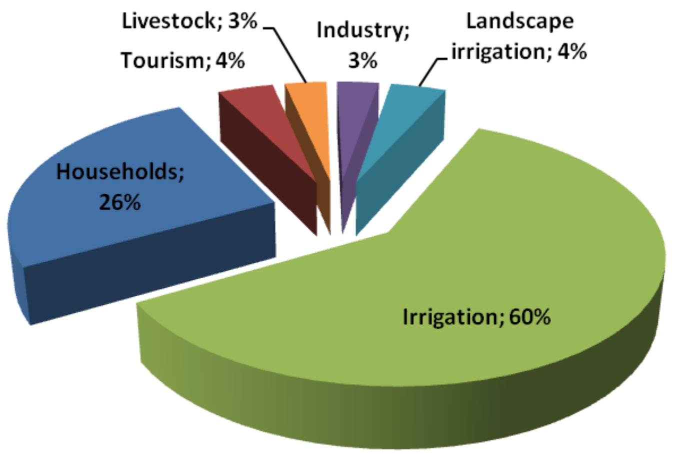


Figure 3-3: Allocation of total water consumption per sector for 2011

It must be mentioned that water demand exceeds the amount of available freshwater resources. For instance, the total demand for irrigation in agriculture is rarely met. After 1996, the demand in agriculture was fully met only during the hydrological year of 2004, when all dams had overflowed.

3.2.1.5 Water Supply

The Republic of Cyprus in order to satisfy total water demand delivered a number of water works for the exploitation of the available freshwater resources, such as dams. In spite of those measures the dependence of water availability from rainfall continues. The long and frequent drought periods have proven that the storage of rain water in dams does not ensure water sufficiency in long term. For this reason, the exploitation of non freshwater resources (sea water, recycled water) has been promoted. Following, the abovementioned water resources are described.

Dams

A total of 108 dams and reservoirs have been constructed under the supervision of the Water Development Department, 56 of these are large dams. The combined storage capacity of the dams is 332 Mm^3 (WDD, 2011a – Annex VII). None of the dams is used for hydro-electric power, which is considered unfeasible due to the limited and infrequent flow of the streams. By the standards of the International Commission of Large Dams (ICOLD), Cyprus is the first in Europe regarding the number of dams per square kilometer.

Groundwater abstractions

The total volume of groundwater abstractions is estimated at 131 Mm^3 annually. The average annual volume of artificial recharge is 10 Mm^3, while approximately 8 Mm^3 of recycled water is used for irrigation, mainly in the groundwater bodies of Kokkinoxoria, Kiti-Perivolia and Akrotiri. The suggested volume of abstraction from all groundwater bodies is 104 Mm^3 annually. This volume of abstraction does not deteriorate the qualitative and quantitative status of groundwater bodies (WDD, 2011a – Annex VII).

The use of groundwater for domestic purposes is the main source for the majority of the villages. In addition, both irrigation and drinking water supply in mountain villages are exclusively satisfied from boreholes. Intension of the Government Water Policy is to progressively reduce the use of groundwater all over Cyprus for domestic purposes, due to its shortage and the deterioration of its quality (Savvides et al., 2001).

Desalination plans

Up to date, two permanent Desalination Plants are operative in Cyprus to full capacity, the ones of Dhekelia and Larnaca, with a total capacity of 122.000 m^3/day. For the short term management of drought, two mobile plants were put in operation in 2009 in Moni (20,000 m^3/day) and in the Garilli river bed (10,000 m^3/day). Furthermore, a mobile plant in Pafos is operating since 2010 with a capacity of 30,000 m^3/day (WDD, 2011a – Annex VII).

The total amount of water produced from desalination plants for public water supply (52.8 Mm^3) covered 64% of total demand (82.1 Mm^3) for 2010 (See Figure 3-4).

Recycled water

Recycled water is a resource which has been given increased attention in recent years. The importance of this resource is particularly large for countries with a dry climate and even more for countries whose development has led the supply-demand balance to negative rates, as in the case of Cyprus. Providing recycled water for irrigation through Government Water Works reached 12 Mm^3 in 2010, from which 9 Mm^3 was supplied for irrigation and about 3 Mm^3 for artificial recharge of aquifers (WDD, 2011a – Annex VII).

Figure 3-4 and Figure 3-5 summarize the allocation of water from Government Water Works to the domestic and agricultural sector for the period 1991-2010 while Figure 3-6 shows the total water supply from Government Water Works.

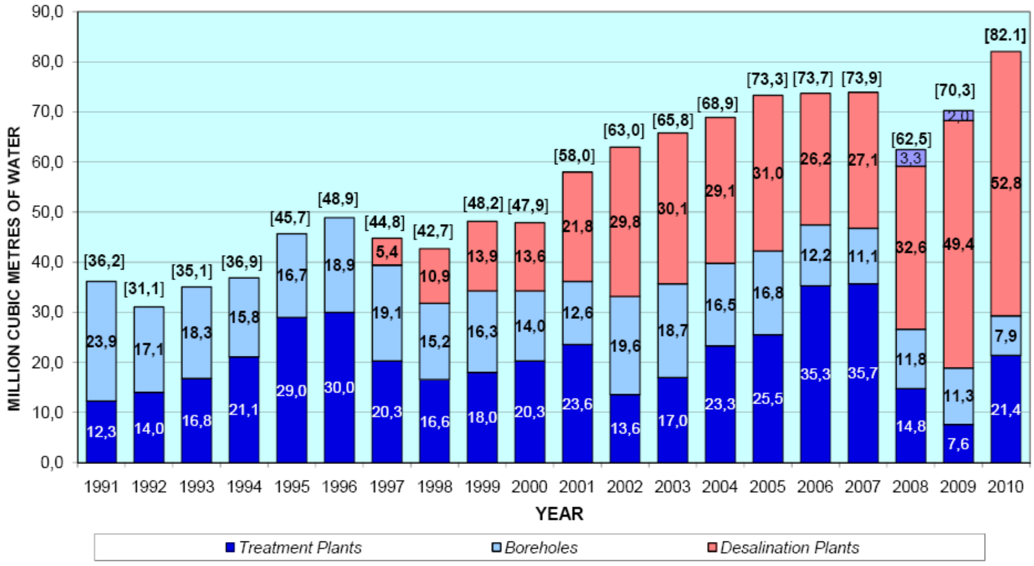


Figure 3-4: Allocation of water from Government Water Works to the domestic sector, 1991-2010

Source: WDD (2)

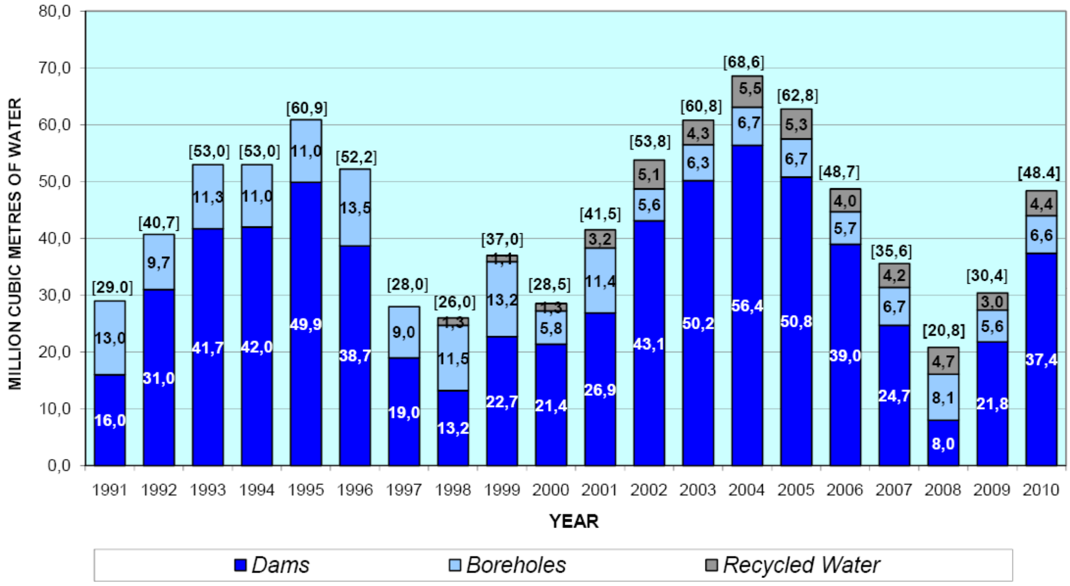


Figure 3-5: Allocation of water from Government Water Works to irrigation purposes, 1991-2010

Source: WDD (3)

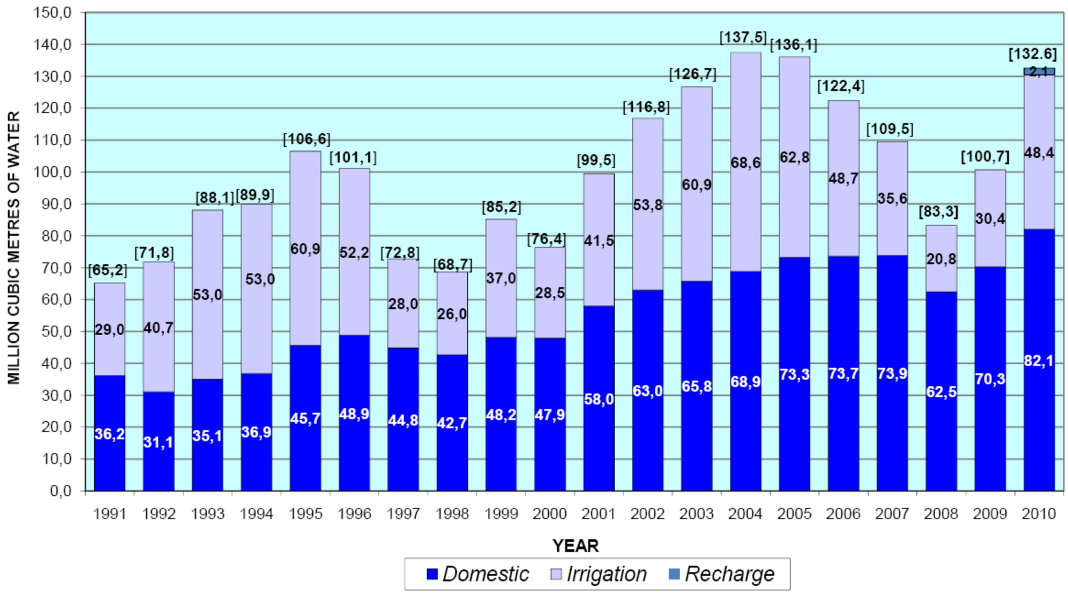


Figure 3-6: Allocation of water supply from Government Water Works, 1991-2010

Source: WDD (4)

3.2.1.6 Water balance

For the period 2000-2010 the total average water demand was 250 Mm^3. However, the available freshwater resources (217 Mm^3) could not cover the total demand. This gap (42 Mm^3) was covered by non-freshwater resources (desalination and recycled water)(WDD). The allocation of water supply sources used in order to satisfy water demand in the period 2000-2010 are presented in Figure 3-7.

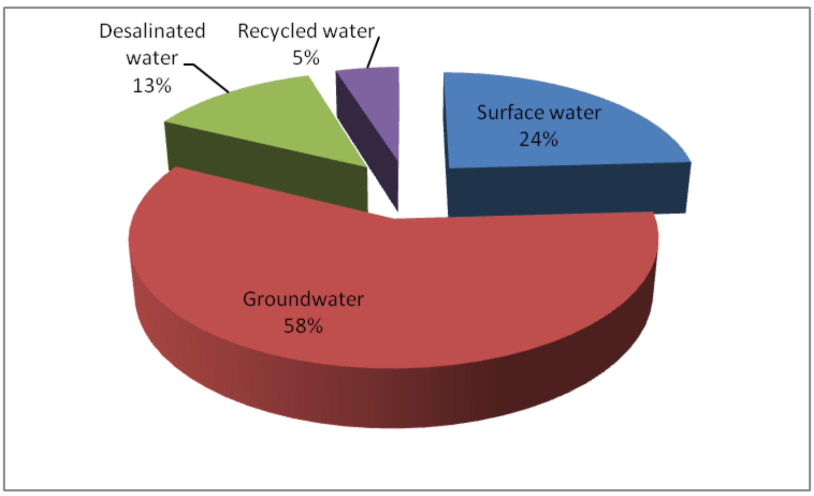


Figure 3-7: Water sources used for the satisfaction of water demand in Cyprus (average for the period 2000-2010)

3.2.2 Summary of pressures on the water sector

The water sector currently experiences both quantitative and qualitative pressures from several environmental and socio-economic activities and practices.

The quantitative pressures are the result of the continuous increase in water demand for all uses and the deficits observed in the water balance. In addition, water resources are stressed due to excess groundwater abstractions. During the last decade, almost all the groundwater bodies are being overexploited, meaning that the amount of groundwater abstracted exceeded the sustainable limit. Furthermore, the consequences of greenhouse gas emissions from desalination plants deteriorate the position of Cyprus in terms of the total quantities of CO_2 emissions.

The qualitative stresses are mainly attributed to point pollution sources which, for the case of Cyprus can be summarized as follows:

- Municipal wastewater, where there are collective sewerage systems and central wastewater treatment facilities
- The livestock waste in organized farms
- Industrial waste and waste from large technical installations
- The solid waste disposal sites
- The mining - quarrying to a lesser extent
- The aquaculture, desalination plants and ports to the marine environment, also to a lesser extent.

3.3 Impact assessment

Climate warming observed over the past several decades globally is consistently associated with changes in a number of components of the hydrological cycle and hydrological systems such as changing precipitation patterns, precipitation intensity and extremes, widespread melting of snow and ice, increasing atmospheric water vapour, increasing evaporation and changes in soil moisture and runoff (Bates et al., 2008). The correlation between the observed changes in climate and the current or potential impacts on water resources for the case of Cyprus is presented in Table 3-1.

Table 3-1 : Relationship between observed climate changes and impacts on the water sector

Observed change	Impact
Increased temperature	Increased water temperatures Increase in evaporation
Increased evapotranspiration	Water availability reduction Lower replenishments rates (lower groundwater levels) Salinisation of water resources
Decreased precipitation, including increased droughts	Decrease in runoff More widespread water stress Increased water pollution and deterioration of water quality due to lower dissolution of sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt Decreased rates of groundwater recharge Salinisation of coastal aquifers due to overpumping motivated by insufficient water supply
Increase in interannual precipitation variability	Increase in the difficulty of flood control and reservoir utilization during the flooding season
Increase in heavy precipitation events	Flooding Adverse effects in quality of surface water and groundwater Contamination of water supply Lower replenishment rates in the aquifers of the mountain areas due to steep slopes
Increase in surface water temperature	Increased algae growth and reduced dissolved oxygen levels in water bodies which may lead to eutrophication and loss of fish Prolonged lake stratification with decreases in surface layer nutrient concentration and prolonged depletion of oxygen in deeper layers Changes in mixing patterns and self purification capacity Salinisation of water resources
Sea level rise	Salinisation of coastal aquifers (minor effect)

The impacts of climate change on water resources are further analyzed in the following sections of this chapter. These are grouped in four impact categories, namely (i) decrease in water availability, (ii) deterioration of water quality, (iii) increase in flood frequency and intensity, and (iv) increase in drought frequency and severity.

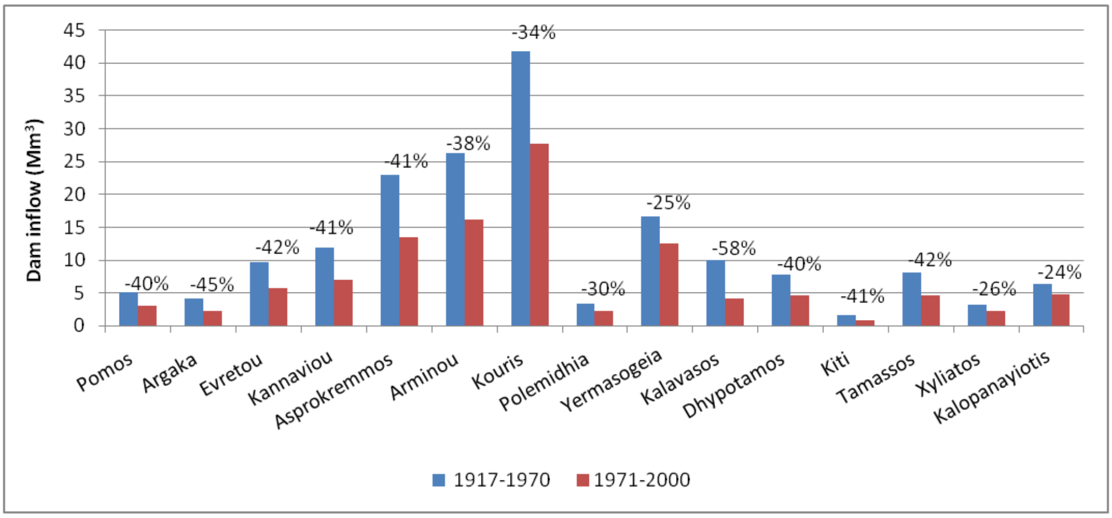
3.3.1 Decrease in water availability

Changes in temperature, precipitation patterns and snowmelt can have impacts on water availability (Parry et al., 2007). Climate change is projected to lead to major changes in yearly and seasonal water availability across Europe. More specifically, southern and south-eastern regions, which already suffer most from water stress, will be particularly exposed to reductions in water resources. Decreased summer precipitation results to a reduction of water stored in reservoirs fed with seasonal rivers. There is very high confidence that many of the areas located in the Mediterranean basin will suffer a decrease in surface and groundwater resources due to climate change (Kundzewicz et al., 2007). In Cyprus, the observed diminished precipitation and increased potential evapotranspiration, directly linked to the temperature increase, indicate that water availability is threatened.

Surface water resources

Changes in river flows due to climate change depend primarily on changes in the volume and timing of precipitation, as well as on changes in evaporation. Over the 20th century, changes in precipitation patterns and temperature in southern parts of Europe led to a slightly decreasing trend in annual river flows (Milly et al., 2005). However, an increase in extreme high river flows is also projected for large parts of Europe due to the increase in heavy rain events, even in regions that will become drier on average. Climate change is projected to result in strong changes in the seasonality of river flows across Europe with decreasing summer flows in most of Europe (EEA/JRC/WHO, 2008).

In Cyprus, the mean quantity of runoff during the period 1971-2000 reduced by 40% compared with the period 1917-1970 with a respective mean precipitation reduction around 13% (Rossel, 2002). In Figure 3-8 the change in the inflow to the main dams of Cyprus for the period 1917-2000 is presented.



* 1917-1970: Design estimates

* 1970-2000: Actual dam inflow

Figure 3-8: Change in inflow to the main dams of Cyprus for the period 1917-2000

Source: Rossel, 2002

Groundwater resources

The reduction in precipitation and the increase in evaporative demand will also lead to a reduction in groundwater levels. A change in the amount of effective rainfall and in the duration of the recharge season will alter recharge rates (Kundzewicz et al., 2007). In addition, high intensity precipitation favors runoff against groundwater recharge.

The climatological conditions that prevail in the island of Cyprus in conjunction with the intense agricultural development that took place during the second half of the previous century and the subsequent increased demand for irrigation had as a result the overexploitation of Cyprus' aquifers. More particularly, a negative balance to most of the aquifers and a reduction in the groundwater levels is observed since 1960. This is also the case for the period from 2005 to 2008 when the prolonged drought had adversely affected the recharge of aquifers, which resulted in a drop of groundwater levels up to 8 meters in the groundwater bodies of Central and Western Mesaoria. However, rainfalls during the hydrologic year 2009/10 had been beneficial since a partial upturn was observed to some groundwater bodies (GSD, 2010).

From the monitoring of the 19 groundwater bodies of Cyprus during the period 2000-2008, it was observed that the level of 10 groundwater bodies had a downward trend and only 3 groundwater bodies had an upward trend while the rest groundwater bodies had a fluctuating trend (WDD, 2011a – Annex VII).

Table 3-2: Level trends in groundwater bodies for the period 2000-2008

Groundwater body	Groundwater level trend
CY_1 Kokkinochoria	Upward-Fluctuating
CY_2 Aradippou Gypsum	Downward-Fluctuating
CY_3 Kiti-Pervolia	Fluctuating
CY_4 Zigi-Softades	Steady-Fluctuating
CY_5 Maroni Gypsum	Steady or Downward
CY_6 Mari-Calo Chorio & Chirokitia Sandstone	Downward
CY_7 Germasogeia	Steady-Controlled
CY_8 Limassol	Fluctuating
CY_9 Akrotiri	Fluctuating-Upward
CY_10 Paramali-Avdimou	Fluctuating-Downward
CY_11 Paphos	Fluctuating-Downward at eastern parts
CY_12 Letimvou-Giolou	Steady-Upward
CY_13 Pegeia	Downward

Groundwater body	Groundwater level trend
CY_14 Androlikou	Steady-Upward
CY_15 Chrisochou-Gialia	Downward
CY_16 Pyrgos	Downward at coastal parts
CY_17 Central and Western Mesaoria	Downward
CY_18 Lefkara-Pachna	Downward-Fluctuating
CY_19 Troodos	Fluctuating

Source: WDD, 2011a

3.3.2 Deterioration of water quality

According to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), it is believed with high confidence that higher water temperatures, increased precipitation intensity, and longer periods of low flows exacerbate many forms of water pollution. However, there is no evidence for climate related trend in water quality (Parry et al., 2007). The main climate-related causes of water quality deterioration are attributed to (i) flow variation, (ii) increased temperatures and (iii) increased salinization of groundwater bodies.

For Cyprus, as a result of increased evapotranspiration rates, an additional cause should be considered. Surface water bodies in Cyprus are mainly the storage reservoirs with no inflows during the summer months. As a result there is no dilution and combined with high evapotranspiration rates their quality is bound to be deteriorated. In addition increasing temperatures will result to increased eutrophication rates, stratification and low levels of dissolved oxygen.

In Cyprus, a trend in water quality deterioration is mainly observed in groundwater resources. The rapid urbanization in various parts of Cyprus during the last 30 years as well as the direct discharge of wastewater in the aquifers, gradually deteriorated the quality of Cyprus' groundwater. Nitrate pollution problems appeared in the aquifers of major residential areas due to the disposal of wastewater in septic tanks and absorbent cesspools. Intensive cultivation and excessive use of fertilizers contributed to the pollution of groundwater with nitrates. Also, increased salinity has been observed in the coastal aquifers, caused by human activity due to over-pumping (WDD, 2008).

The deterioration of groundwater quality worsens by climate factors which lead to a low recharge rate, as the latter leads to the increase of pollutants concentration in groundwater. In addition, climate changes in Cyprus have led to the elongation of the irrigation period, thus creating an increased water demand in agriculture which led to aquifer over-pumping.

Furthermore, climate factors boost natural processes causing water quality deterioration. More specific, the low recharge rate of aquifers in combination with the low permeability of some sedimentary aquifers in Cyprus, results in the dissolution of soluble salts and the increase in salinity (WDD, 2008).

In order to extract safe conclusions regarding the impact of climate changes on water quality, the following are considered necessary:

- Data availability from a long monitoring period
- Correlation of water quality with climatic conditions and clear distinction of the effect from human activities

3.3.3 Increase in flood frequency and intensity

Despite the considerable rise in the number of reported major flood events and economic losses caused by floods in Europe over recent decades, no significant general climate related trend in extreme high river flows that induce floods has yet been detected. Although there is yet no proof that the extreme flood events of recent years are a direct consequence of climate change, they may give an indication of what can be expected: the frequency and intensity of floods in large parts of Europe is projected to increase (Lehner *et al.*, 2006; Dankers and Feyen, 2008). In particular, flash and urban floods, triggered by local intense precipitation events, are likely to be more frequent throughout Europe (Christensen and Christensen, 2007; Kundzewicz *et al.*, 2006). Flood hazard will also probably increase during wetter and warmer winters, with more frequent rain and less frequent snow (Palmer and Räisänen, 2002)(EEA/JRC/WHO, 2008).

Cyprus in spite of the fact that is characterized by long and frequent dry periods, also suffers from flooding events. In Cyprus during the last forty years (1971-2010), 340 flooding events[3] were recorded (WDD, 2011d). From Figure 3-9, it can be seen that the frequency of flooding events has increased considerably during the period 2000-2010 in comparison with the period 1970-2000, as 61% of the total flooding events refer to that period.

According to the IPCC, increases in the intensity of precipitation, may result in more frequent and hazardous flooding events. Pluviometrical data from the meteorological station in Nicosia (1930-2007) show an increase in the intensity and quantity of precipitation of 37-49% for the period 1970-2007 in comparison with the period 1930-1970 for a duration of precipitation between 5 minutes and 6 hours (Pashiardis, 2009). Historical records of the Water Development Department (WDD) on flooding events for the period 1859-2011 (WDD, 2011b – Annex III), show an increase in the flooding events in Cyprus for the same period, as 71 flooding events (mostly flash floods) were recorded during the period 1930-1970, while in the period 1971-2010 recorded flooding events have tripled (207 flooding events). However,

[3] An event in the WDD study (2011d) is a location where a flood had negative effects. Thus, there are often many events for a single rainfall-runoff event.

it must be mentioned that the data recorded during the period 1930-1970 are not considered exhaustive, as the recording mechanisms at that time were inadequate. Furthermore, this increase is attributed mainly to a number of other factors such as urbanization (increase of the built-up urea) and changes in land uses without taking the appropriate measures (river bed protection zones, flood protection works), and secondarily to climate changes.

The number of flooding events in Cyprus during the period 1971-2010 as well as their hazard ranking (very low, low, moderate, high) in terms of adverse consequences for human health, the environment, cultural heritage and economic activity are presented in the following figure.

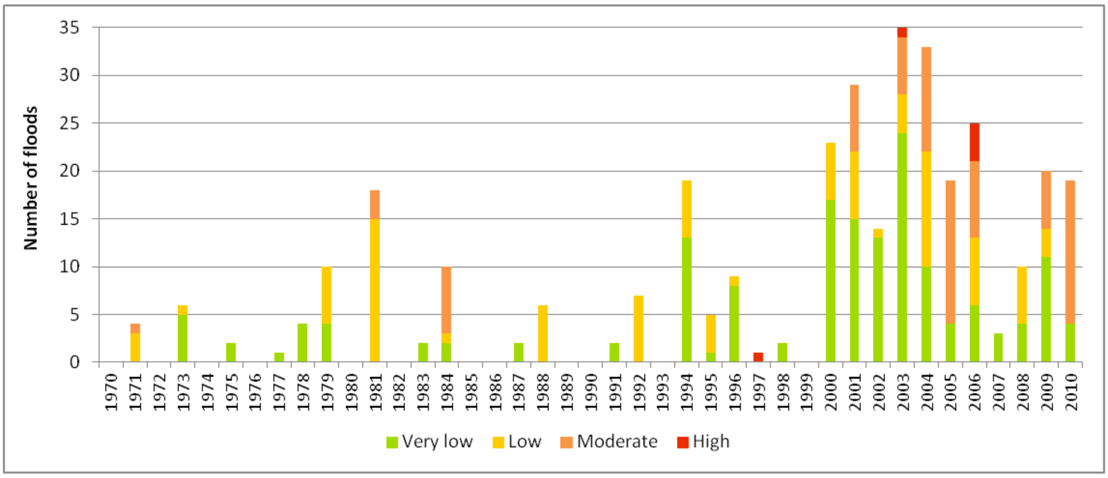


Figure 3-9: **Number of flooding events per year in Cyprus (1971-2010) (CYPADAPT)**

Source: WDD, 2011d

3.3.4 Increase in drought frequency and severity

Droughts affect water availability and water quality. Southern and south-eastern regions in Europe show significant increases in drought frequencies (Kundzewicz et al., 2007). During 2000-2009, Europe has been affected repeatedly by drought. In 2008, Cyprus suffered a fourth consecutive year of low rainfall and the drought situation reached a critical level in the summer of that year (EEA, 2010).

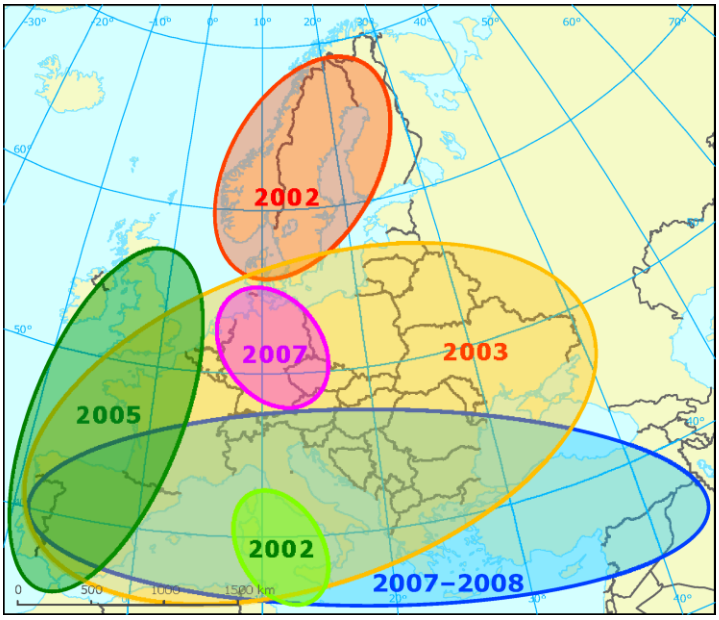


Figure 3-10: Main drought events in Europe, 2000–2009

Source: EEA, 2010

Another study of the EC (2007) shows that Cyprus registered among the highest frequencies of droughts in Europe in the period 1976 to 2006, with a large part of its territory being affected whenever droughts occurred (Figure 3-11).

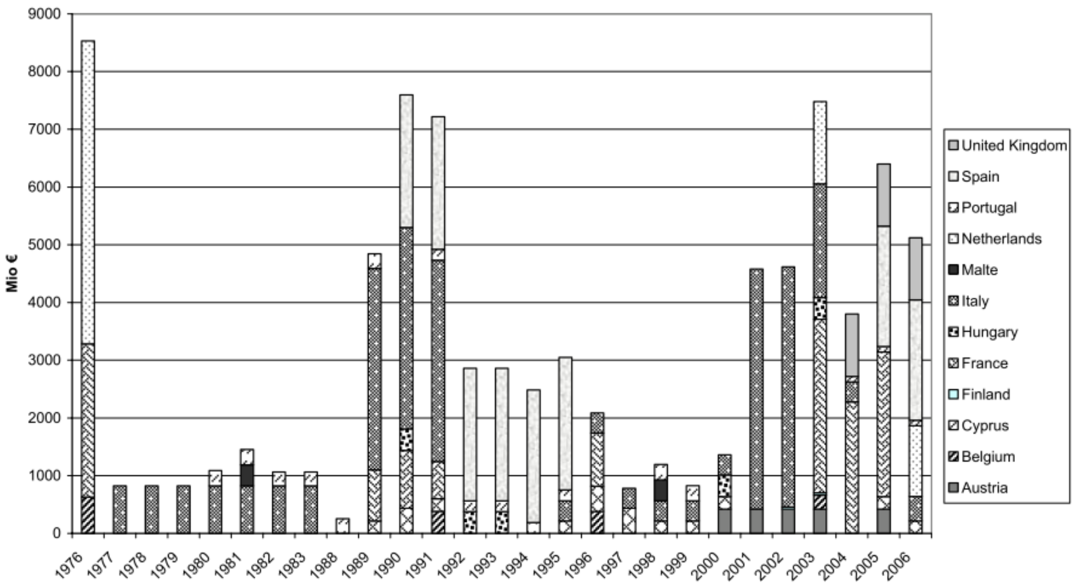


Figure 3-11: Drought impact per year and Member State (1976 – 2006)

Source: EC, 2007

In Cyprus, droughts may last one or several years. The Meteorological Service of Cyprus categorized the hydrological years based on the normal precipitation of the period 1961-90 (503mm). From Figure 3-12, it can be seen that the years with precipitation above normal appear to decline or even to extinguish the last decade as the last "extreme wet" year was observed in 1968-69, the last “wet” year in 1991-92 and the last “above normal” year in 2002-03. On the other hand, many years with precipitation below normal were observed during the last decade with the year 2007-08 being characterized as a year of severe drought (<70% normal) and 2005-06 as a year of drought (71-80% normal).

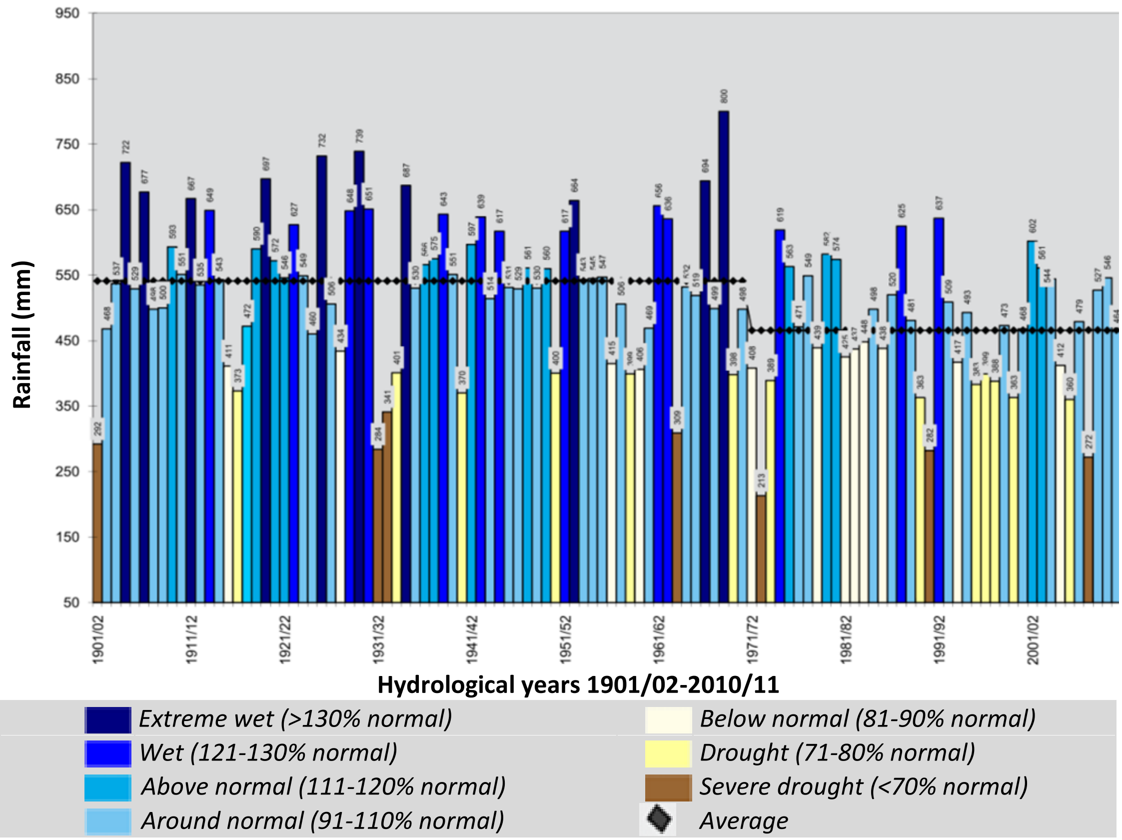


Figure 3-12: Mean annual precipitation in Cyprus (area under Government control)

Source: WDD (5)

3.4 Vulnerability assessment

In this section, the vulnerability of water resources to climate change impacts is assessed in terms of their sensitivity, exposure and adaptive capacity, based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which water resources are affected by climate changes, exposure is the degree to which water resources are exposed to climate changes and their impacts while the adaptive capacity is defined by the ability of water resources to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The indicators used for the assessment of sensitivity, exposure and adaptive capacity of Cyprus water resources to climate change impacts are summarized in Table 3-3.

Table 3-3: Indicators used for the vulnerability assessment of climate change impacts on the water resources of Cyprus

Vulnerability variable	Selected Indicators
Water availability	
Sensitivity	– Sensitivity of runoff to changes in rainfall – Dam inflow variability – Number of groundwater bodies overexploited – Number of groundwater bodies in bad quantitative status – Freshwater availability per capita – Water Exploitation Index – Water availability index – Number of years water demand exceeded amount of available freshwater resources
Exposure	– Number of dams presenting decreasing trend – Number of groundwater bodies in bad quantitative status
Adaptive capacity	– Increase water storage capacity – Inter-basin water transfer – Artificial aquifer recharge – Water import – Use of desalinated water – Use of treated water – Stormwater use – Replacement of networks – Improving water use efficiency in irrigation – Water allocation – Control groundwater overexploitation – Use of water supply meters

Vulnerability variable	Selected Indicators
	– Redistribution of irrigated land – Water pricing – Subsidies for drinking water savings – Awareness campaigns – Improving monitoring and forecast
Water quality	
Sensitivity	– Effect of climatic factors, such as temperature and rainfall, on the quality of water resources – Reduction of the rate of aquifer replenishment – Overexploitation of aquifers due to water scarcity
Exposure	– Percent of river water bodies in bad ecological and chemical status – Percent of lake water bodies in bad ecological and chemical status – Percent of coastal water bodies in bad ecological and chemical status – Number of surface water areas identified as sensitive according to the Directive 91/271/EEC – Surface Water Vulnerability (SWV) Index – Number of groundwater bodies with excess pollutant concentrations – Number of groundwater bodies declared as Vulnerable Nitrate Zones (VNZ), according to the Directive 91/676/EEC – Number of groundwater bodies salinized – Number of groundwater bodies in bad qualitative status
Adaptive capacity	– Designation of protected areas – Protection from point source discharges likely to cause pollution to water – Action Programme to prevent or reduce water pollution from nitrates – Protection from point source discharges likely to cause pollution to water – Protection of groundwater bodies from salinization – Expansion of existing sewage treatment plants
Floods	
Sensitivity	– Percent of very high and high hazard flooding events taking place in Cyprus
Exposure	– Areas with potential significant flood risk in Cyprus
Adaptive capacity	– Development of a separate drainage system for the collection of stormwater – Implementation of Sustainable Urban Drainage Systems – Identification of flood risk areas – Preparation of Flood Risk Management Plans

Vulnerability variable	Selected Indicators
Droughts	
Sensitivity	– Sensitivity to Desertification Index – Percent of areas characterized as semi arid with an increased sensitivity – Percent of areas immediately threatened
Exposure	– Number of consecutive years of drought – Amount of deficit during drought periods – Frequency of drought periods – Percent of years characterized as 'severe drought' and 'drought' years – Standardized Precipitation Index (SPI)
Adaptive capacity	– Elaboration and implementation of a Drought Management Plan

*There were no data regarding this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from "none" to "very high".

In the sections that follow, the vulnerability is assessed for each of the impact categories presented in Section 3:

1. Water availability
2. Water quality
3. Floods
4. Droughts

In must be noted that, further research is required in order to correlate the status of water resources with climate change impacts and indicators and to provide concrete information for a more detailed assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability.

3.4.1 Water availability

3.4.1.1 Assessment of sensitivity and exposure

Sensitivity and exposure of water availability to climate changes in Cyprus is assessed by the sensitivity of runoff to changes in rainfall which results in increased flow variability and the exposure to limited water supply safety. Additional exposure to pressures, imposed on freshwater resources by non climatic factors, such as water demand and groundwater overexploitation also increase the vulnerability of the sector. In the following sections, the indicators used for the evaluation of sensitivity and exposure of the sector are presented.

3.4.1.1.1 Sensitivity of runoff to changes in rainfall

River flows in arid and semi-arid regions like Cyprus are highly sensitive to changes in rainfall. A given percentage change in rainfall can produce a considerably larger percentage change in runoff. As shown in Figure 3-13, the total surface runoff in Cyprus during the hydrological years 1987/88-2010/11 decreased at a higher rate than the reduction in precipitation, which is best represented with a logarithmic trendline.

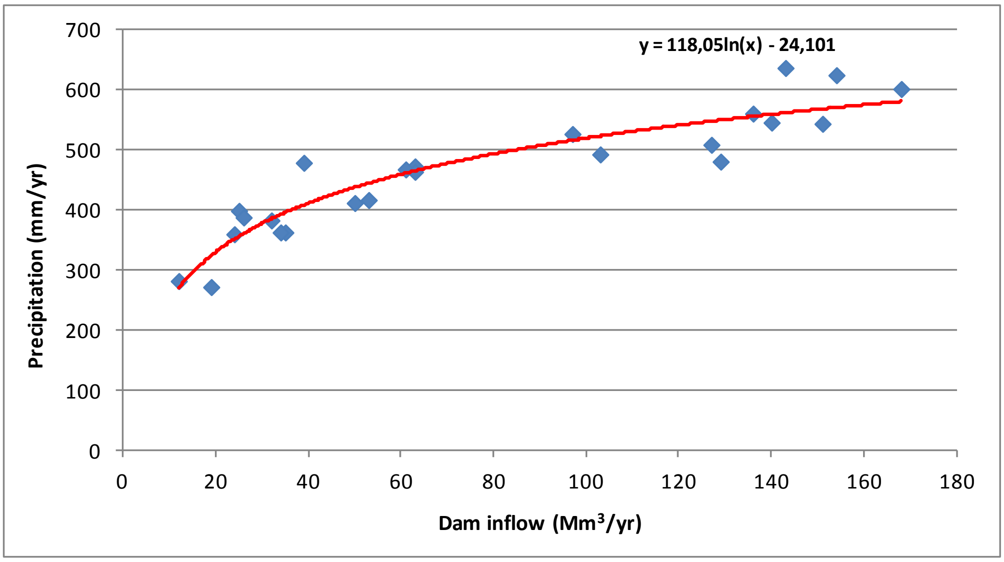


Figure 3-13: Relationship of rainfall and dam inflow in Cyprus (1987/88-2010/11)

During the period 1971-2000 the total quantity of water impounded in the 15 main reservoirs of Cyprus, as well as, runoff reduced by 40% compared with the design estimations for the period 1917-1970 with a respective mean precipitation reduction around 13% (Rossel, 2002). In Table 3-4 the change in rainfall and inflow to the catchment area of the main dams of Cyprus for the period 1917-2000 is presented.

Table 3-4: Change in rainfall and inflow to the catchment area of the main dams of Cyprus (1917-2000)

No	Dam catchment area	Change (%)	
		Dam inflow	Rainfall
1	Pomos	-40%	-16%
2	Argaka	-45%	-16%
3	Evretou	-42%	-17%
4	Kannaviou	-41%	-15%
5	Asprokremmos	-41%	-16%
6	Arminou	-38%	-15%
7	Kouris	-34%	-13%
8	Polemidhia	-30%	-10%
9	Yermasogeia*	-25%	-10%
10	Kalavasos	-58%	-15%
11	Dhypotamos	-40 %	-14%
12	Kiti	-41%	-10%
13	Tamassos	-42%	-18%
14	Xyliatos	-26%	-13%
15	Kalopanayiotis	-24 %	-13%
	Average	**-39%**	**-14%**

Source: Rossel, 2002

As it can be seen in Table 3-4, all main dams in Cyprus have been exposed to decreased inflow due to decreased precipitation, with the magnitude of exposure ranging from -24% to -58% in the period 1917-2000 (high exposure).

Figure 3-14 shows, as an example, the relation between annual rainfall and runoff for the catchment of the Kouris dam for the period 1916/17-1999/2000, where a 34% decrease in annual runoff was observed for a 13% decrease in annual rainfall for this catchment.

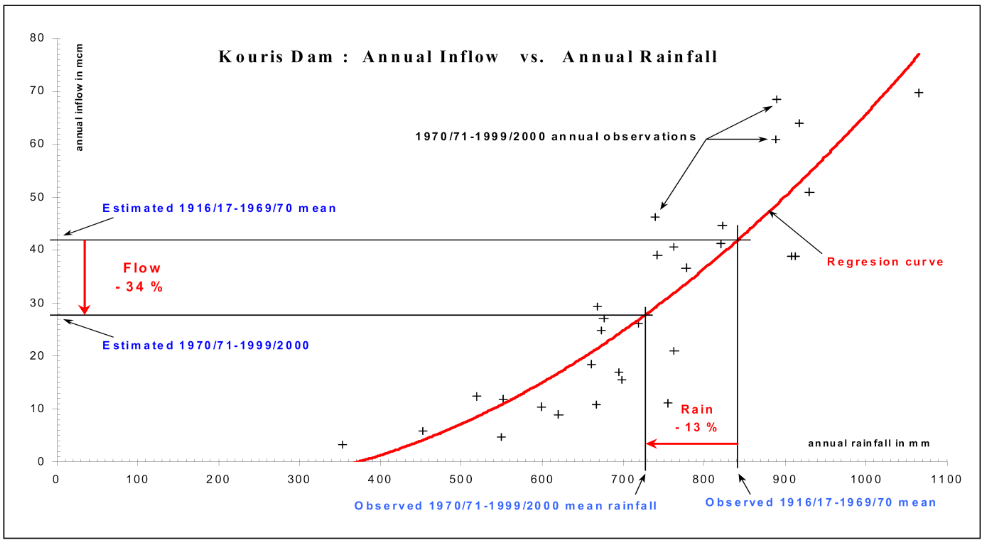


Figure 3-14: Relation between annual precipitation and annual inflow to the catchment area of the Kouris dam for the period 1916/17-1999/2000

Source: Rossel, 2002

3.4.1.1.2 Dam inflow variability

The Flow Variability Index was used to estimate water supply safety for Cyprus. This indicator is calculated by estimating the standard deviation of annual inflows to the dams of Cyprus. A low value indicates a low variability of runoff and thus reduced sensitivity of water availability, while high variability indicates increased sensitivity in this aspect. In Figure 3-15 it can be seen that there is high variability in dam inflow for the period 1987/88-2010/11 (average dam inflow: 78.5 Mm^3/yr, standard deviation: 52.1 Mm^3/yr) and thus high sensitivity of Cyprus surface water resources to climate changes.

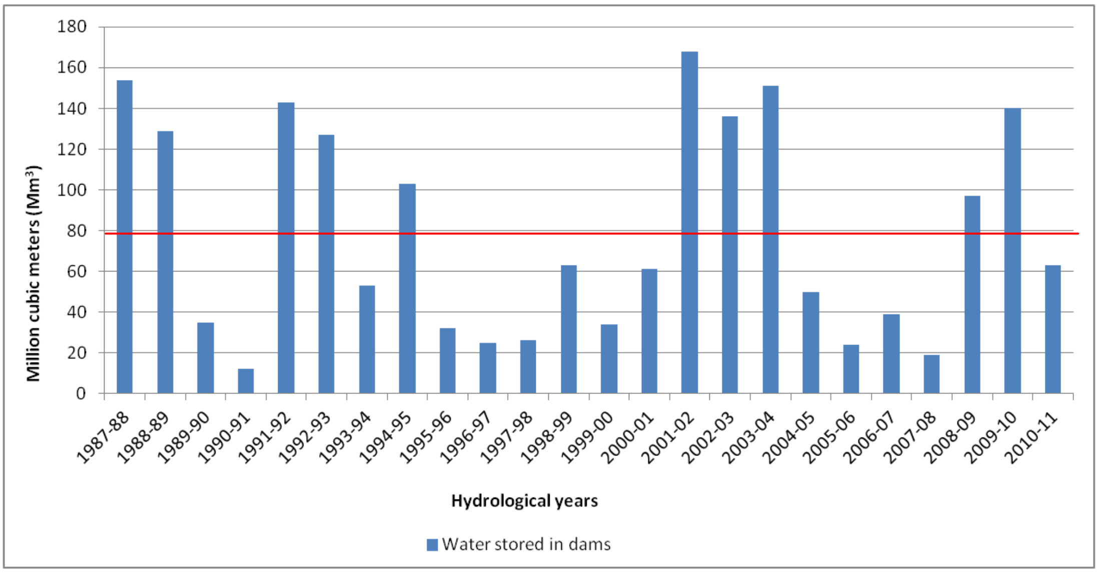


Figure 3-15: Variability of flow into the dams of Cyprus for the hydrological years 1987/88-2010/11

Source: WDD (6)

3.4.1.1.3 Groundwater overexploitation

Diminishing precipitation and increased evapotranspiration with consecutive years of drought led to the depletion of surface water stored in reservoirs and the exploitation of aquifers (direct climate change effect) especially for agriculture as the irrigation period elongated. Furthermore, cuts in water supply by Government works imposed in periods of drought or high water pricing have often led private water consumers to illegally abstract water from boreholes (indirect climate change effect), which resulted in further deterioration of groundwater quantitative status.

Figure 3-16 shows that only 2 from the 19 groundwater bodies in Cyprus are not over-pumped (non sustainable abstraction[4]) revealing the intense pressure posed on them.

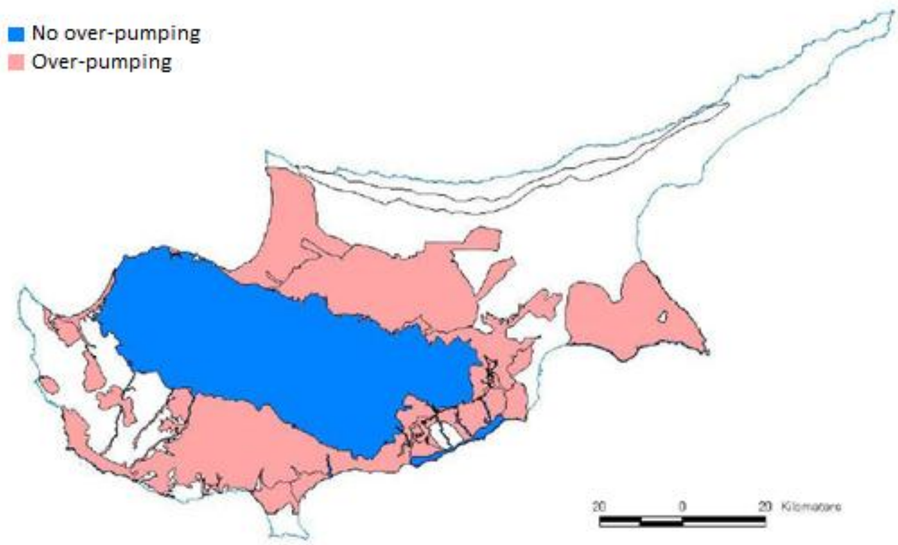


Figure 3-16: Over-pumping in the groundwater bodies of Cyprus

Source: WDD, 2008

According to the Water Framework Directive, which takes into consideration the trends in groundwater bodies level as well as the amount of unsustainable groundwater abstraction, 11 from 19 groundwater bodies are considered to be in bad quantitative condition (Table 3-5). Given that a large percent of groundwater bodies have been exposed directly or indirectly to climates changes, Cyprus' groundwater resources are characterized by high exposure to climate change.

Table 3-5: Quantitative status of groundwater bodies in Cyprus, 2000-2008

No of groundwater body	Groundwater level trend	Over-pumping (Mm^3/yr)	Condition
CY_1 Kokkinochoria	Upward-Fluctuating	4.5	BAD

[4] Non sustainable abstraction refers to the amount of water that is abstracted in excess of the sources' recharge as a fraction of the total water abstractions.

No of groundwater body	Groundwater level trend	Over-pumping (Mm^3/yr)	Condition
CY_2 Aradippou Gypsum	Downward-Fluctuating	0.5	GOOD
CY_3 Kiti-Pervolia	Fluctuating	1.1	BAD
CY_4 Zigi-Softades	Steady-Fluctuating	0.7	BAD
CY_5 Maroni Gypsum	Steady or Downward	0.7	GOOD
CY_6 Mari-Calo Chorio & Chirokitia Sandstone	Downward	0.4	BAD
CY_7 Germasogeia	Steady-Controlled	0	GOOD
CY_8 Limassol	Fluctuating	0.9	BAD
CY_9 Akrotiri	Fluctuating-Upward	2.4	BAD
CY_10 Paramali-Avdimou	Fluctuating-Downward	0.7	BAD
CY_11 Paphos	Fluctuating-Downward at eastern parts	0.5	GOOD
CY_12 Letimvou-Giolou	Steady-Upward	0.1	BAD
CY_13 Pegeia	Downward	1.1	BAD
CY_14 Androlikou	Steady-Upward	0	GOOD
CY_15 Chrisochou-Gialia	Downward	0.3	GOOD
CY_16 Pyrgos	Downward at coastal parts	0.3	GOOD
CY_17 Central and Western Mesaoria	Downward	6.7	BAD
CY_18 Lefkara-Pachna	Downward-Fluctuating	3	BAD
CY_19 Troodos	Fluctuating	3	GOOD

Source: WDD, 2011a

3.4.1.1.4 Freshwater stress indicators

Water stress is often related to the deterioration of fresh water resources in terms of both quantity and quality (Hochstrat & Kazner, 2009). Already stressed water resources are considered more vulnerable to climate changes. The difficulty facing Cyprus in order to meet water demand either for satisfying drinking water supply or for other purposes such as agriculture, tourism and industry, due to water stress, indicates the sensitivity of the sector to climate changes.

Following, the indicators used for the quantification of water stress caused by the decreased quantity of available freshwater resources in Cyprus are presented. It is noted that, these indicators refer exclusively to the exploitation of freshwater resources, while non freshwater resources (desalinated water, recycled water) are not taken into account.

Freshwater availability per capita

The Falkenmark Water Stress Indicator (Falkenmark, 1989) divides the volume of available water resources for a country by its population. Its threshold values indicate that water availability of more than 1,700m^3/capita/year is defined as the threshold above which water shortage occurs only irregularly or locally. Below this level, water scarcity arises in different levels of severity. Below 1,700m^3/capita/year water stress appears regularly, below 1,000m^3/capita/year water scarcity is a limitation to economic development and human health and well-being, and below 500m^3/capita/year water availability is a main constraint to life. However, the above index does not take into consideration the available amount of non freshwater resources in a country.

The Water Stress Indicator (WSI) per capita was calculated for the part of Cyprus which is under Government control, by dividing the average annual quantity of available freshwater resources (surface water stored in reservoirs and groundwater) in the free part of Cyprus (2000-2010) by the population of the Republic of Cyprus. Given that there were available data on population from two censuses (2001, 2011), their average was used for the estimation of WSI in order to best reflect the population of the period under examination. The estimated WSI value of 284 m^3/capita/year is considered very low, which shows that it is not possible to rely exclusively on freshwater resources.

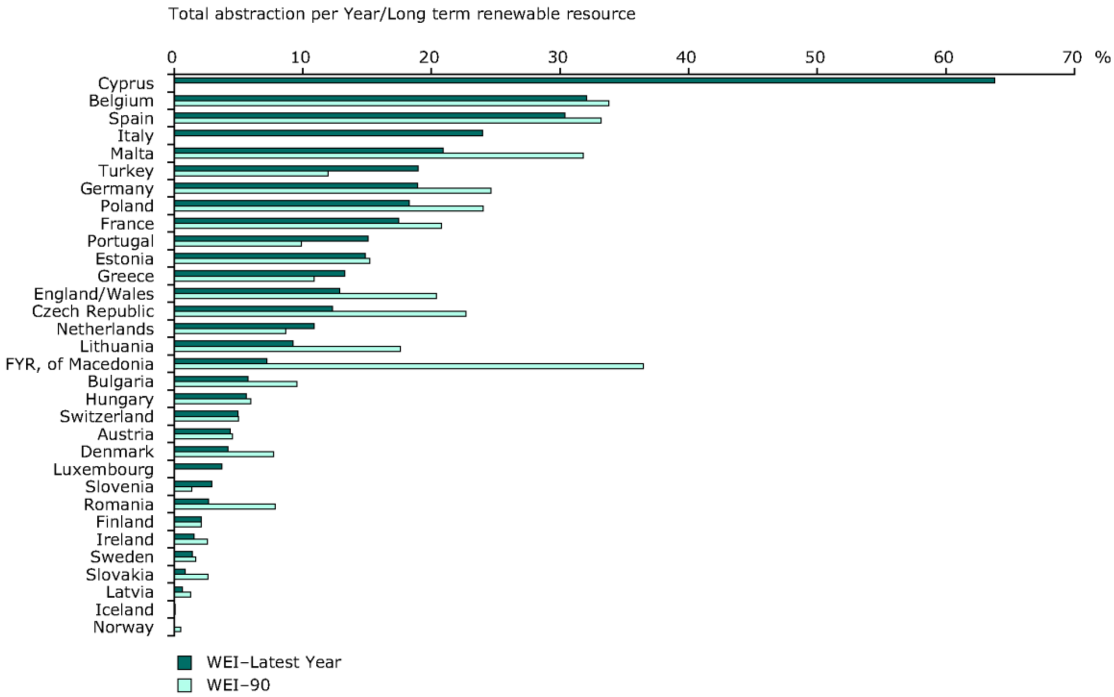
$$WSI = \frac{available\ freshwater\ resources\ (avg.2000-2010)}{population\ (avg.2001-2011)} = \frac{217\ Mm^3}{764{,}231} = 284\, m^3/capita\,/year$$

Water Exploitation Index

One relatively straightforward indicator of the pressure or stress on freshwater resources is the Water Exploitation Index (WEI). It relates water availability and water use and is defined as the ratio of annual water withdrawal from ground and surface water to the total renewable freshwater resources. Hence high water stress indices can either be caused by low availability and/or excessive high water demand (EEA, 2010b).

$$WEI = \frac{total\ freshwater\ abstractions}{total\ renewable\ resources}$$

A WEI above 20 % implies that a water resource is under stress and values above 40 % indicate severe water stress and clearly unsustainable use of the water resource (Raskin *et al.*, 1997). As shown in Figure 3-17, the WEI of Cyprus for the year 2007 was 64%, which is by far the highest WEI value among the European countries.



Note: Annual total water abstraction as a percentage of available long-term freshwater resources around 1990 (WEI-90) compared to latest year available (1998–2007) (WEI-Latest Year).

(WEI Latest year, WEI-90) = Cyprus (2007, -); Belgium (2005, 1994); Spain (2006, 1991); Italy (1998, -); Malta (2007, 1990); Turkey (2001, 1990); Germany (2004, 1991); Poland (2005, 1990); France (2006, 1991); Portugal (1998, 1990); Estonia (2007, 1990); Greece (2007, 1990); UK* (England/Wales) (2006, 1990); Czech Republic (2007, 1990); Netherlands (2006, 1990); Lithuania (2007, 1990); FYR, of Macedonia (1990, 2007); Bulgaria (2007, 1990); Hungary (2002, 1992); Switzerland (2006, 1990); Austria (1999, 1990); Denmark (2004, 1990); Luxembourg (1999, -); Slovenia (2007, 1990); Romania (2007, 1990); Finland (1999, 1990); Ireland (2007, 1994); Sweden (2007, 1990); Slovakia (2007, 1990), Latvia (2007, 1991); Iceland (2005, 1992); Norway (- , 1985)

Figure 3-17: Water exploitation index (WEI) in Europe (1990-2007)

Source: EEA, 2010c

Water availability index

The Water Availability Index, WAI (Meigh et al., 1999) takes into account surface water and groundwater resources, and compares the total amount to the demands of all sectors, i.e. domestic, industrial and agricultural demands. The index is normalised to the range –1 to +1. A score of –1.0 indicates that there is negligible water available to meet demands, whilst a score of 0.0 indicates that the available water meets the demands and a score of 1.0 indicates that the available water is much greater than the demands (WSM, 2004). In the case of Cyprus, WAI is estimated to be approximately -0.1 for the period 2000 – 2010, indicating that the demand is higher than the availability of freshwater sources (WDD[4]).

$$WAI = \frac{available\ freshwater\ resources - demand}{available\ freshwater\ resources + demand} = \frac{217\ Mm^3 - 249\ Mm^3}{217\ Mm^3 + 249\ Mm^3} = -0.07$$

Decreased precipitation and increased evapotranspiration due to temperature increase led to decreased water availability, while the increase in demand due to population increase and the rising of living standards added an extra pressure in the already limited freshwater resources. From Figure 3-18 it can be seen that water demand exceeded available freshwater resources in the period 2000-2010 for 7 out of 11 years.

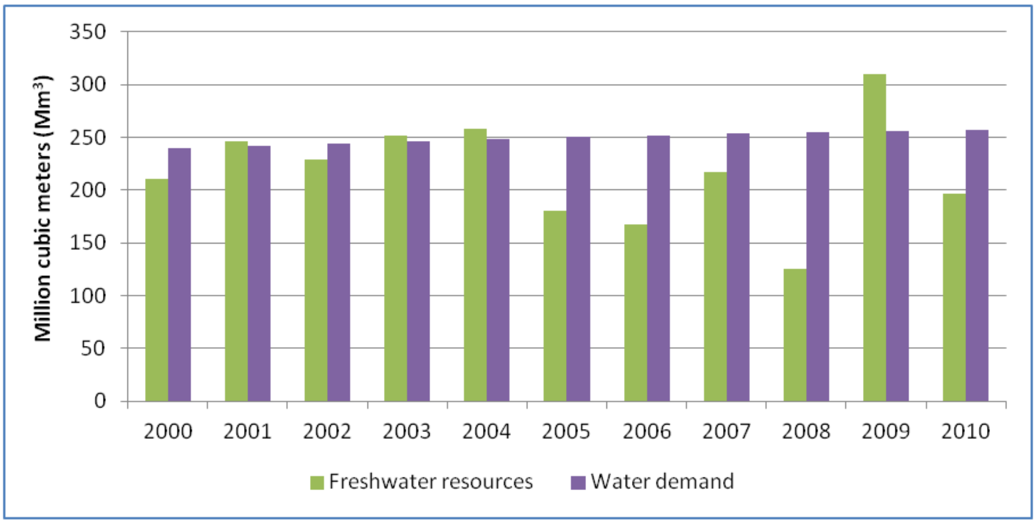


Figure 3-18: Water demand and freshwater resources in Cyprus for the period 2000 – 2010

Source: WDD[5]

Taking into consideration the above, Cyprus' water availability is considered to have **very high** sensitivity to climate changes, as the quantity of water resources is directly linked with changes in rainfall and evapotranspiration resulting in increased flow variability, limited water supply safety and overexploitation of freshwater resources.

Furthermore, water availability in Cyprus is considered to have **very high** exposure to climate changes, as all reservoirs and the majority of groundwater bodies in Cyprus have recorded a decreasing trend.

3.4.1.2 Assessment of adaptive capacity

In Cyprus the continuous expansion of population and industry resulted in the increase of water demand, while the impacts from climate change have reduced the country's water supply. In order to combat this gap, several measures, plans and water works have been implemented by the Government. The WDD has put a number of measures in place to reduce water demand and to diversify water supply such as the production of desalinized sea water, the use of non-conventional sources such as the use of recycled water, the efficient use of available water including the better use of pricing and water conservation measures, the protection, preservation and improvement of the water quality, the introduction of new effective management procedures through the establishment of a

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

Water Entity and the development of the remaining existing water resources with the construction of dams until 2015 (WDD, 2011a).

The Programme of Measures defined in the Cyprus River Basin Management Plan includes inter alia measures which are expected to reinforce Cyprus' adaptive capacity to the decreasing availability of freshwater resources and thus to climate change. These measures include controls of abstraction and impoundment of water, measures promoting the efficient and sustainable water use, utilization of surface water resources from projected works, demand management measures (WDD, 2011a). The water demand management that have been identified include: replacement of networks, use of non-conventional water resources, subsidy and financial support programmes, scenarios of water allocation, use of water meters, stormwater use, redistribution of irrigated land, further improvement of irrigation efficiency, water pricing, educational campaigns for water saving (WDD, 2011c).

In addition, a series of administrative measures (extended operation of water boards at district level, extension of sewerage boards operation at district level), economic and fiscal measures (establishment of the "Water Fund") are also expected to reduce water consumption and thus enhance water availability in Cyprus (WDD, 2011a).

The abovementioned adaptation measures as well as their status of implementation are presented in Table 3-6, while in the following sections a brief assessment of the effectiveness of the main measures is conducted.

Table 3-6: List of measures to adapt Cyprus' water management to climate change impacts

Adaptation measures	Implemented	Planned	Prescriptive	Legally binding	Incentives
Measures to increase water supply					
Reservoirs	X				
Inter-basin water transfer	X				
Artificial recharge of aquifers	X	X			
Water import	X				
Diversification of water resources utilisation					
Water reuse	X	X			
Desalination	X	X			
Stormwater harvesting		X			
Measures to decrease water consumption					
Replacement of networks	X	X			
Water allocation/cuts	X	X			
Use of water meters	X	X			
Redistribution of land	X	X			
Increasing efficiency of irrigation	X	X	X		X
Control groundwater abstractions	X			X	
Changes in crop patterns		X	X		X
Awareness raising campaigns	X				X
Economic/legal instruments					
Subsidies	X	X			X
Water pricing	X	X			
Over consumption penalties	X	X			
Other instruments					
Improving forecasting, monitoring, information - alert system	X	X			

3.4.1.2.1 Measures to increase water supply

Reservoirs

The capacity of dams has significantly increased since 1960 from 6 Mm^3 to 332 Mm^3 (Figure 3-19). As a result, the accumulated storage capacity in 2010 was able to cover 4 times the average annual dam inflow of the period 1987-2010 (78.5 Mm^3). This practice has reached physical limits as favourable sites are not available and even more because, as presented in previous sections, there is no increasing trend in precipitation and natural run-off expected. However, main aim of the construction of a plethora of dams is to capture as must as possible of the surface runoff and to eliminate water losses to sea.

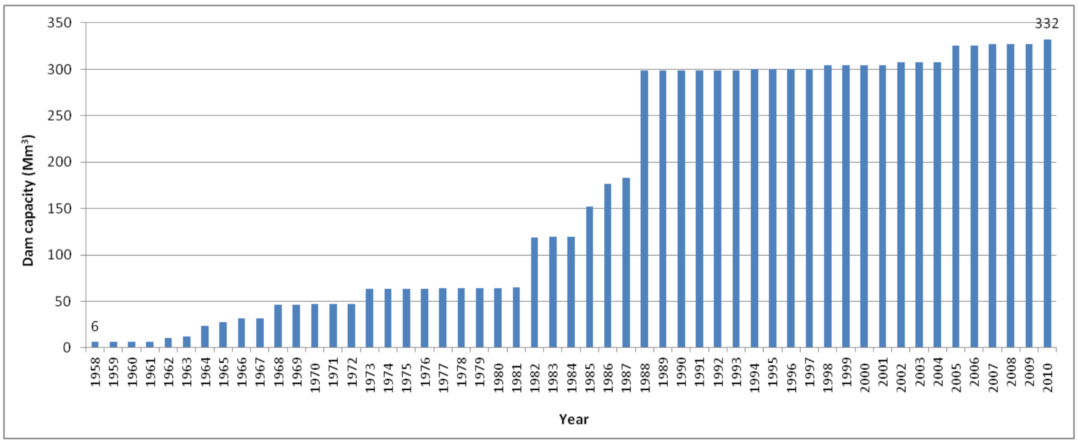


Figure 3-19: Accumulated capacity of dams in Cyprus for the period 1958 – 2010

Inter-basin water transfer

The interconnection of reservoirs and conveyor systems allows distribution of water across the island and offer some flexibility in operation. Existing water infrastructure involves large inter-basin transfers in the South-South-eastern (South Conveyor Project - SCP) and in the South West-Western (Pafos Irrigation Project) parts of the island. This allows for considerable flexibility in water management and allocation in most areas.

Artificial aquifer recharge

The construction and operation of a large number of dams in conjunction with the increasing demand and abstractions, has led to reduced natural recharge of downstream aquifers. Artificial recharge includes all works relating to the deliberate acceleration of recharge rate of aquifers from surface water sources and constitutes a key priority in the management of groundwater resources in Cyprus. However, it must be mentioned that in order to fully replenish the water lost from the aquifers it is expected to take at least 12 years assuming that no water is being extracted from the aquifer during that period.

Water import

Emergency water was shipped into the island from Greece during summer 2008. This unprecedented action was vital to supply Limassol with drinking water and earmarked the extraordinary severity of the drought. A total of 8 Mm^3 was planned to be delivered from June to November for a total expenditure of around 40 million EUR. In fact the daily delivery was only 35,000 m^3. According to the Water Development statistics, the imported amount in 2008 was 3.3 Mm^3 (Hochstrat & Kazner, 2009).

3.4.1.2.2 Measures for the diversification of water resources utilisation

The use of non conventional water resources such as desalinated water, treated water from WWTPs, grey water and stormwater in water supply for various uses can substantially alleviate the pressures on the freshwater resources which are already high in Cyprus (see Section 3.4.1.1.4: Freshwater stress indicators). Following, the progress made so far in Cyprus regarding the use of non conventional water resources is presented.

Desalination

Desalination constitutes a secure source for safe drinking water supply, once demand management measures are fully implemented. Government policy of Cyprus is the complete independence of the water supply of the urban and tourist areas from rainfall and the satisfaction of the maximum demand during the summer period, using desalination plants. Within this framework, the Water Development Department has prepared a Desalination Plan which foresees the operation of 5 Permanent Desalination Plants by 2012, with a total production of 252,000 m^3/day. The contribution of desalination plants to domestic water supply for 2010 amounted to 65% which equals 55.5 Mm^3, while is expected to increase significantly after the operation of the additional desalination plants.

The desalination capacity has increased from 40.000 m^3/d in 1997 when the first desalination plant in Cyprus operated to 182,000 m^3/d in 2011 and will reach a capacity of 252,000 m^3/d in 2012. Table 3-7 summarizes the desalination plants in operation and their respective capacities for the years 1997, 2011 and 2012.

Table 3-7: Desalination plants in operation for the years 1997, 2011 and 2012

Desalination plant	Capacity (m^3/d)		
	1997	2011	2012
Dekelia	40,000	60,000	60,000
Larnaca	-	62,000	62,000
Lemesos	-	-	40,000
Pafos	-	-	40,000
Moni (mobile)	-	20,000	-
Pafos (mobile)	-	30,000	-
Vasiliko	-	-	50,000
Garilli (mobile)	-	10,000	-
Total	**40,000**	**182,000**	**252,000**

Source: WDD, 2011a

However, desalination is an energy intensive process producing a residue (brine) that must be carefully treated and disposed in order to prevent environmental degradation. Hence, desalination could be considered a mal-adaptation measure unless certain requirements are taken into account, such as the use of renewable energy and the proper treatment and disposal of brine produced.

Use of treated municipal effluents

The use of treated wastewater provides additional drought-proof water supply, favours a more local sourcing of water and avoids the use of high quality water sources where this is not necessary. The potential for water reuse depends on the availability and accessibility of wastewater, hence the wastewater infrastructure, and the acceptability by potential end-users and consumers. Providing recycled water for irrigation through Government Water Works, began in 1998, with a small amount of around 1.3 Mm^3 and reached 12 Mm^3 in 2010, from which 9 Mm^3 was supplied for irrigation and about 3 Mm^3 for artificial recharge of aquifers.

There is an immense potential for growth of water reuse practices driven by both the demand for water and the increasing volumes of treated effluent. Aiming for compliance with the Urban Wastewater Treatment Directive (91/271/EEC) requirements, the wastewater collection and treatment infrastructure is being significantly expanded and upgraded. As shown in Table 3-8, the capacity of the new Waste Water Treatment Plans in 2012 amounts to 59 Mm^3 per year and will reach up to 65 Mm^3 per year over the medium term (2015) and 85 Mm^3 for long-term (2025). The annual water recycling is expected to reach 28.5% of today's agricultural water demand (WDD, 2011a- Annex VII).

Table 3-8: **Estimated volumes of treated wastewater for the years 2012, 2015, 2025**

	Quantity of treated wastewater (Mm^3/year)		
	2012	2015	2025
Municipal wastewater treatment plants	46	51	69
Rural wastewater treatment plants	13	14	16
Total	**59**	**65**	**85**

In general, the treatment of wastewater in Cyprus includes tertiary processes followed by filtration. Treated wastewater is used for the irrigation of green spaces, athletic fields and crops (excl. edible raw vegetables) as well as for aquifer recharge.

Further treatment of certain quantities of the effluent with the process of reverse osmosis (RO) is under consideration, in order for water salinity to be reduced and the final effluent to be used for the irrigation of sensitive soils and crops. At the same time, the reverse osmosis process is expected to enable the integrated management of all irrigation water resources. However, the application of reverse osmosis presents some disadvantages, such as the high costs for the construction and operation of RO plants, and more significantly, the difficulty in selecting a management option for the brine produced which will be both techno-economically feasible and socially accepted. For example, the suggestion for thermal treatment of the brine from the RO plant, which is proposed to be constructed in the area of Aradippou, is socially acceptable but is quite expensive, while the conventional disposal of the untreated brine is not considered (WDD, 2011A – Annex VII).

General aim is to use the increasing quantities of treated effluents produced for the irrigation of the agricultural crops thus substantially alleviating the pressures posed to the sector due to water scarcity.

Furthermore, treated wastewater is also used in Cyprus for aquifer recharge. So far treated wastewater from Paphos and Agia Napa-Paralimni is used for the recharge of Ezousa's aquifer. The expansion of this measure to the aquifer of Kiti and Kokkinochoria is under investigation as well. This will be decided on the basis of the quality of the treated (WDD, 2011A – Annex VII).

Aquifer recharge offers an opportunity to store water in order to use it in periods of decreased availability and/or increased demand. However, there is stakeholder opposition to groundwater recharge due to water quality concerns related to the risk of drinking water resources pollution. Quality of reclaimed water has always been an issue, but to date, the problem of micro-pollutants has not been considered yet. Though reclaimed water has to be analysed for bulk parameters and selected metals, no organic micropollutants are being monitored so far (Hochtsrat & Kazner, 2009).

<u>Stormwater use</u>

The use of storm water can result in further savings in fresh water consumption. The last two decades, a separate drainage system is being developed in Cyprus in order to collect stormwater. So far, the drainage network in the majority of the big urban centres of Cyprus has been completed.

Furthermore, the Sewerage Board of Limassol-Amathus in cooperation with the five municipalities of the Greater Limassol area as well as the wider area of Paphos began the implementation of Sustainable Urban Drainage Systems (SUDS). SUDS are actually a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water. Up to now, no suitable measures have been identified for the case of Larnaca due to its topography (low-lying area).

Further research must be made on this field for the evaluation of the potential use of storm water. In this framework, a study was conducted by the WDD (WDD, 2009) in order to explore the potential use of storm water.

3.4.1.2.3 Measures to decrease water consumption

<u>Replacement of networks</u>

Water losses in domestic water distribution networks, mainly in rural areas, are quite high. The "unaccounted for" water in the main urban domestic supply distribution networks is estimated in the range of 15 to 20% and about 20 to 30% in the rural areas. Therefore, an additional effort should be made for the timely identification and replacement of defective pipes and for developing a more conscious attitude towards water conservation.

Water saving from the replacement of networks is expected to be very important compared to other possible water saving measures. From research conducted during the period 2009 – 2010 for the Water Supply networks of the municipalities (that does not belong to Water Supply Boards), more than 80% of the networks have been replaced for the 63.4% of the municipalities (WDD, 2011c).

Improving water use efficiency in irrigation

A Water Use Improvement Project has been implemented by the Department of Agriculture since 1965. According to this project the government provided farmers with technical and financial assistance to turn from traditional surface irrigation methods to modern irrigation methods. The progress in the irrigation efficiency from less than 45% in 1960, reached 71% in 1980, 80% in 1990, 84% in 2000 and 90–95% in 2010. The on-farm irrigation systems comprise 90% micro-irrigation, 5% sprinkler irrigation and 5% surface irrigation (WDD, 2011c).

The *Water Efficiency Index* allows the monitoring of progress in terms of the water saved as a result of demand management by reducing loss and wastage during both the transport and use of water. It is subdivided into total and sectoral efficiency (drinking water, agriculture and industry). In Cyprus water efficiency in irrigation is lower in comparison to that of drinking water (Figure 3-20). As shown in Figure 3-21, total water use efficiency in Cyprus rose from 65% in 1995 to 82% in 2005-2010 (Plan Blue, 2011).

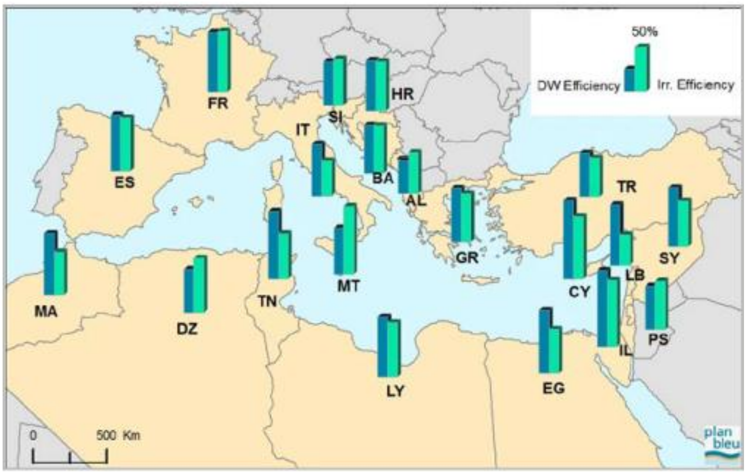


Figure 3-20: Water use efficiency in two sectors (drinking water and irrigation) in 2010

Source: Plan blue, 2011

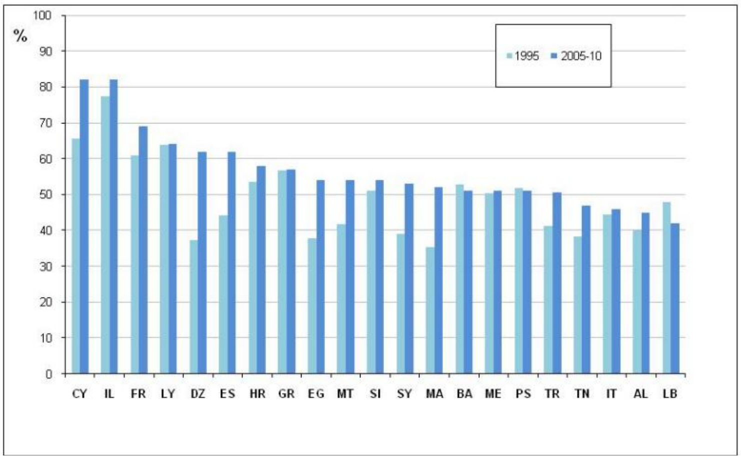


Figure 3-21: Total water use efficiency in Mediterranean countries (1995, 2005-2010)

Source: Plan blue, 2011

Water allocation

Water allocation mechanisms under drought conditions (water rationing) have been established to provide priority to maintaining domestic and municipal water supplies. The second priority is to maintain supplies to perennial crops at 80% of the recommended application levels. Seasonal vegetable crops constitute the third priority. The water cuts in irrigation from the South Conveyor System during the period 2000-2010 ranged from 10% to 90% with the exception of 2004 where the water cuts were equal to zero. The cuts in the drinking water supply ranged from 13% to 23% for the same period (WDD, 2011c).

Control groundwater abstractions

The Law on the Integrated Water Management 79(I)/2010 which has been enforced in Cyprus since 2010, sets the requirements for the granting of permissions regarding borehole drilling and pumping. The Law also foresees the installation and monitoring of water meters in boreholes, in order for the quantities of water pumped not to exceed the limits set. It is expected that with the new Law a considerable number of violations, that have been made in the past, will be eliminated. Furthermore, a proposed amount of annual abstraction from each aquifer is set in order to establish a positive balance between natural recharge and abstractions.

Use of water supply meters

Metered supply allows users to observe their consumption and to follow up effects of water saving measures. The installation of individual water supply meters from the drinking water consumers in Cyprus is almost catholic, while for irrigation purposes it is restricted mainly in areas supplied with water from Government Water Works or from boreholes in certain groundwater bodies that are under Special Water Savings Measures. It has been observed that only the introduction of water meters could achieve water savings of 10 – 25% of the total consumption (WDD, 2011c).

Redistribution of irrigated land

Land redistribution constitutes another measure which is directly linked with the decrease in water demand, through the reduction in the fragmentation of agricultural holdings, the opportunity for scale economies in irrigation works and the achievement of significant water savings. Since 1969, 62 out of 73 submitted redistribution plans referred in irrigated land and 3 in mixed, irrigated and rainfed land. In addition, another 12 plans are in progress and 27 under examination, both referring in irrigated land.

It is difficult to estimate the efficiency of the redistribution of small pieces of irrigated land and its contribution as a water saving measure. However, irrigated areas that have been redistributed have shown increased irrigating efficiency mainly because the application of improved irrigation systems is more feasible in that case, thus resulting in savings in irrigation water (WDD, 2011c).

Water pricing

The water pricing system, as applied today in Cyprus, is not considered to be an effective tool for achieving water savings. It was found that there is no elasticity in water demand in relation to its current price, both in drinking and irrigation water, as the variations in water prices had not affected average water demand. Actually, reductions in water demand were observed during periods of intense water scarcity, which is attributed mainly to the raising awareness campaigns. It must also be mentioned that with the introduction of the new desalination plants, the costs of water production and supply will change significantly and the pricing system will move to a new balance. For that reasons, the Water Development Department has assigned a study for the implementation of appropriate pricing policies of water services as well as for the implementation of penalty charges for overconsumption (quota system). The current pricing system as well as the proposed one is presented below (WDD, 2011a – Annex II):

- *Supply of drinking water from Government Water Works*: So far, drinking water is supplied from Government Water Works to all Districts for a fixed price (the same price was charged to all Districts except Pafos District). The Water Supply Boards, Municipalities and Municipal Boards in their turn charged different block tariffs for the further distribution of water. The new pricing policy is based on increasing block rates and on the full recovery of cost (including the environmental and resource cost).
- *Supply of freshwater for irrigation from Government Water Works*: For the supply of irrigation water, lower prices have been set for uses of high social value (e.g. agriculture) and higher prices for uses of lower social value (e.g. golf courses). The pricing system of irrigation water is based on a two part tariff, the first one being a fixed price reflecting the fixed costs and the second one being a variable cost (volumetric pricing) reflecting the variable costs. However, as a large part of the charge could be covered from the fixed charge, the system was considered ineffective in preventing excessive water use. For that reason, the charges with the new pricing policy were adjusted, reducing fixed cost to 15% of the initial price.
- *Supply of recycled water for irrigation from Government Water Works*: The use of recycled water in irrigation is encouraged, as the charging of this source does not

enhance the cost of its production and supply. In order to further promote the use of recycled water with the new pricing system, its price is proposed to be set at 75% of the freshwater price.

– *Drinking water outside GWW*: So far water from private boreholes is not charged. With the new pricing policy, the abstraction of groundwater will be charged, taking into account the environmental and resource cost of groundwater.

It is expected that with the implementation of the new pricing policy additional water savings will be achieved.

Subsidies for drinking water savings

The WDD has been offering subsidies in order to reduce drinking water consumption mainly in households with the use of untreated groundwater or greywater in certain uses as well as the recycling of hot water. The water-saving subsidies are for (i) the drilling of boreholes for watering gardens, car wash etc, (ii) the installation of a grey water treatment system for watering gardens, (iii) the installation of a hot water recirculator and (iv) the connection of the borehole with the toilet cisterns. In 2009, 1331 applications were approved, the majority of which (594) were for drilling boreholes (WDD, 2011c).

Awareness campaigns

Awareness campaigns are essential in order to achieve water savings. During the last decade the awareness campaigns have been intensified by the WDD, with lectures in schools, advertisements, distribution of informative leaflets and other initiatives. It is difficult to estimate their efficiency in actual water savings, however a downward trend in water consumption was observed during the period 2004-2009 when the campaigns have intensified (WDD, 2011c).

Improving monitoring and forecast

As most problems in the water supply are related to the scarcity of the resource, a close monitoring of the relevant meteorological parameters and the inflow to the dams has been established. Yet in urban areas the rainfall stations should be more numerous to better follow especially heavy rainfall events (Rossel, 2002). The observation of groundwater resources has been less well attended to in the past, which has led to excessive over-pumping of aquifers. Improved monitoring networks are required to collect sufficient and robust data to base an indicator system for the state of the resources on it. The application of leak detection, real time telemonitoring and tele-control to optimize operation and maintenance of networks is among the envisaged measures (Hochstrat & Kazner, 2009).

Table 3-9 lists the demand management measures along with the estimated savings (Mm^3/yr) and the time period (years) used for the estimations. It was estimated that these measures could save a total of 91.4 Mm^3/yr.

Table 3-9: Water demand management measures and estimated savings

Measure	Water savings (Mm^3/yr)	Data coverage (years)
Replacement of water supply networks	3.3	2000-2010

Measure	Water savings (Mm^3/yr)	Data coverage (years)
Use of non-conventional water resources Recycled water Desalinated water Stormwater	 12.5 55.5[1] 0	2005-2008
Subsidies for reducing domestic water demand Borehole drilling Borehole connections with toilets Grey water recycling Hot water circulators	 1.3 0.3 0.03 0.05	1997-2010
Water allocation and cuts	41.5	2000-2010
Use of water meters	8	1986-2009
Redistribution of irrigated land	4.4	1991-2009
Irrigation systems	20	1960-2000[2]
Total	**91.4**	

[1] Desalinated water supply was not included in the demand savings total.
[2] The period 1960-1974 include also the Turkish occupied areas.

Source: WDD, 2011c

Considering that many of the measures adopted have already alleviated the problem of water scarcity, as continuous water supply to the domestic sector has been secured by desalination plants and significant savings have been achieved in water consumption, Cyprus' adaptive capacity to water availability for domestic water supply is considered **high**. On the other hand, the measures applied have not yet managed to fully satisfy water demand for irrigation as agriculture constitutes the second priority of the Government water policy, after meeting the demand of the domestic sector. Given that agriculture requires a great amount of water (over 60% of total water demand), restrictions in water supply for irrigation are a common phenomenon especially during summer when the water resources are limited. Therefore, the adaptive capacity to the water availability for irrigation is considered as **limited to moderate**.

3.4.2 Water quality

3.4.2.1 Assessment of sensitivity and exposure

Water bodies in Cyprus are sensitive to eutrophication, stratification and low levels of dissolved oxygen as a result of increased water temperatures and decreased water flows due to reduced precipitation. The reduction in the recharge rates due to reduced precipitation is more intense in the case of groundwater bodies, thus being more sensitive to climate changes. In addition, coastal aquifers are highly sensitive to salinization due to sea intrusion caused by their over-explotation.

Considering the above, it was estimated that surface water bodies have **moderate to high** sensitivity to pollution due to climate changes while groundwater bodies have high to **very high** sensitivity.

The exposure was estimated based on their existing qualitative status, given that the water bodies that are already in bad qualitative condition are considered more vulnerable to climate change impacts.

In the following sections the qualitative status of Cyprus' water resources for each type of water body is presented in order to assess their exposure.

3.4.2.1.1 Surface water bodies

<u>Status of river water bodies</u>

Based on the results of the monitoring program of Cyprus water, 68 out of the 216 river water bodies (31.5%) were classified in the category of good ecological status / good ecological potential, 76 (35.2%) in moderate, 16 (7.4%) in poor, 3 (1.4%) in bad, while 56 river water bodies (24.5%) remained unclassified (Figure 3-22).

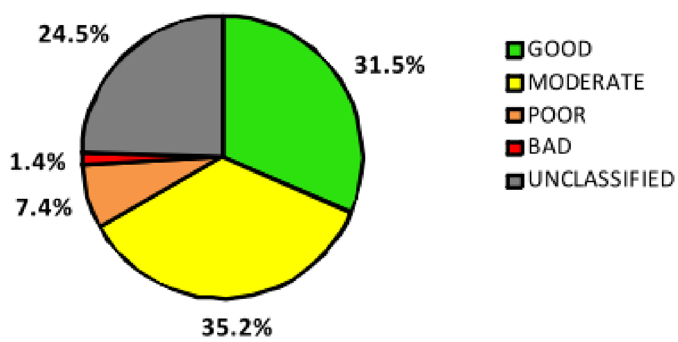


Figure 3-22: Ecological status of river water bodies, (%) number of bodies

Source: WDD, 2011a

Concerning the chemical status of the river bodies, 71.3% were classified in the category of good chemical status and only 4.2% in less than good chemical status, while 24.5% remained unclassified (WDD, 2011a).

Status of lake water bodies

Based on the results of the monitoring program of Cyprus water resources, 10 lake bodies (56%) were classified in the category of good ecological status, 6 (33%) in moderate status, 1 (5,5%) in bad status while 1 (5,5%) was not ranked in any category (Figure 3-23).

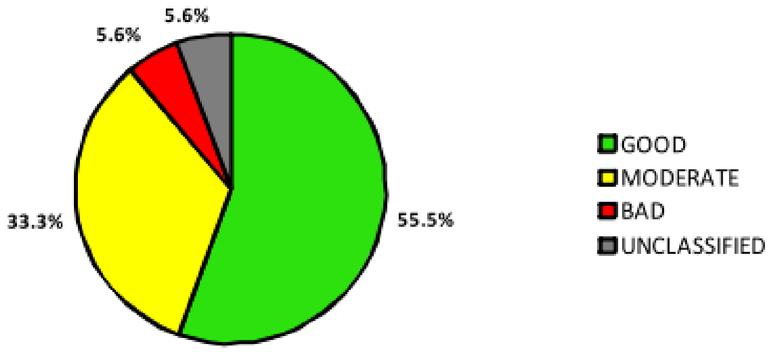


Figure 3-23: Ecological status of lake water bodies, (%) number of bodies

Source: WDD, 2011a

Concerning their chemical status, 72.2% of the lake bodies were found to be in a good chemical status and only 16.7% in a less than good chemical status (5% of the total area of the lake bodies) while 11.1% remained unclassified (WDD, 2011a).

In the following figures (Figure 3-24 and Figure 3-25), the ecological and chemical status of river and lake bodies of Cyprus are depicted in the form of maps.

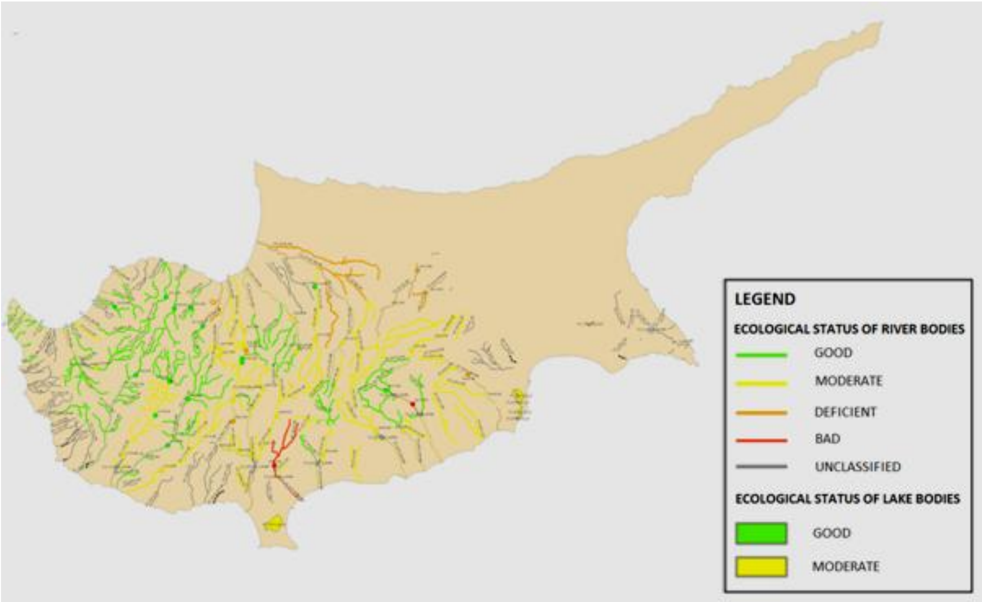


Figure 3-24: Map of the ecological status of river and lake bodies in Cyprus

Source: WDD (7)

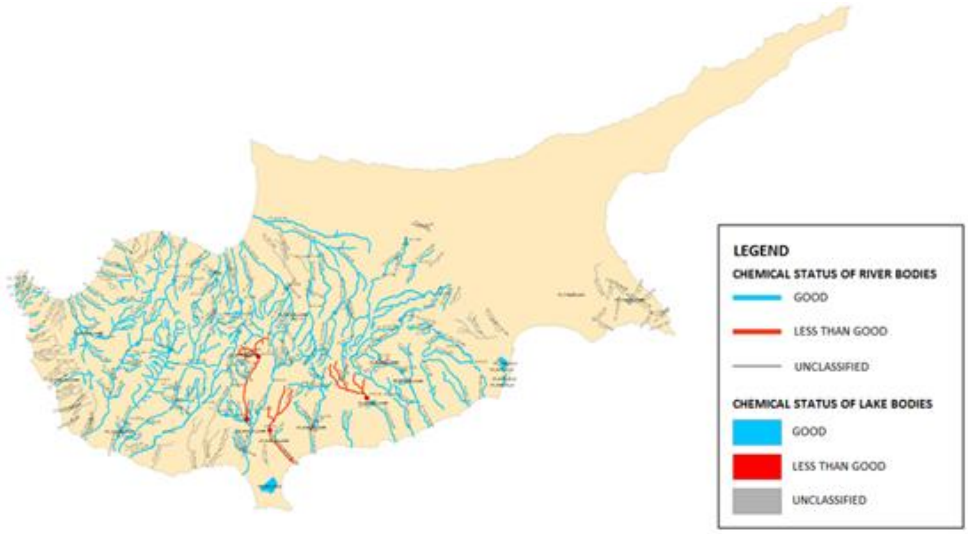


Figure 3-25: Map of the chemical status of river and lake bodies in Cyprus

Source: WDD (8)

As it can be seen, the majority of river and lake bodies of Cyprus were classified in a good or moderate ecological and chemical status.

Status of coastal water bodies

According to data provided from the Department of Fisheries and Marine Research of MANRE, all 25 coastal water bodies were found in good or high ecological status or good ecological potential. Similarly, their chemical status was good (WDD, 2011a).

Sensitive water bodies to pollution from wastewater

Furthermore, in Cyprus two surface water areas, in which direct or indirect disposal of urban waste water takes place, have been identified as sensitive according to the Directive 91/271/EEC. The criteria for the characterization of surface waters as sensitive are the eutrophication or risk of eutrophication, the increased presence of nitrates in water intended for human consumption and the need for further processing to meet requirements of other Directives. These areas are the 'Polemidhia Storage Reservoir' and the 'Coastal Area between Cape Pyla and Paralimni' (see Figure 3-28) (WDD, 2011a – Annex I).

<u>Pollution potential of surface water bodies</u>

Following, the Surface Water Vulnerability (SWV) Index as it was estimated for the case of Cyprus in the framework of the Pig Wasteman project (LIFE Third Countries) is presented. The SWV Index defines the pollution potential of a surface water body and is based on four basic parameters of equal weight, among which one is a climate parameter. The parameters used are the quantity of annual rainfall inducing runoff, the texture of soil which affects the runoff coefficient, the topography in terms of the slope of site from the pollution source toward the surface water, and the distance from the pollution source to the nearest surface water**.** The higher the index is, the greater the relative pollution potential (PigWasteMan, 2007). As it is shown in the figure that follows, the surface waters most vulnerable are located in the central and north-western part of Cyprus.

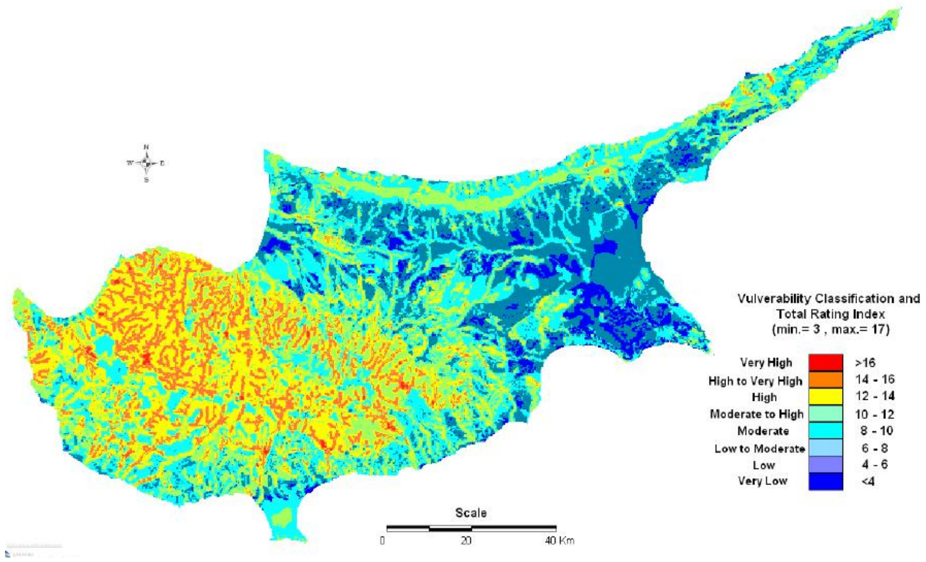


Figure 3-26: Map of surface water vulnerability to pollution

Source: PigWasteMan, 2007

Considering the above, it is estimated that the exposure of surface water bodies to pollution is **limited to moderate**.

3.4.2.1.2 Groundwater bodies

The main matters which have arisen from the results of the monitoring of groundwater quality in Cyprus, were the increased nitrate and chloride concentrations (above the limits) which were found in seven water bodies, while another water body in Paphos is stll under investigation. In addition, increased concentrations of sulphates, ammonium, arsenic, pesticides and increased conductivity were found in several groundwater bodies (see Figure 3-27). The main causes of pollution in Cyprus are agriculture, seawater intrusion and wastewater disposal, while industry constitutes a less significant source of pollution as the number of industries in Cyprus is limited. Moreover, the quality of groundwater in Cyprus is affected by natural causes like geological formations which release sulphate and chloride salts of sodium and boron.

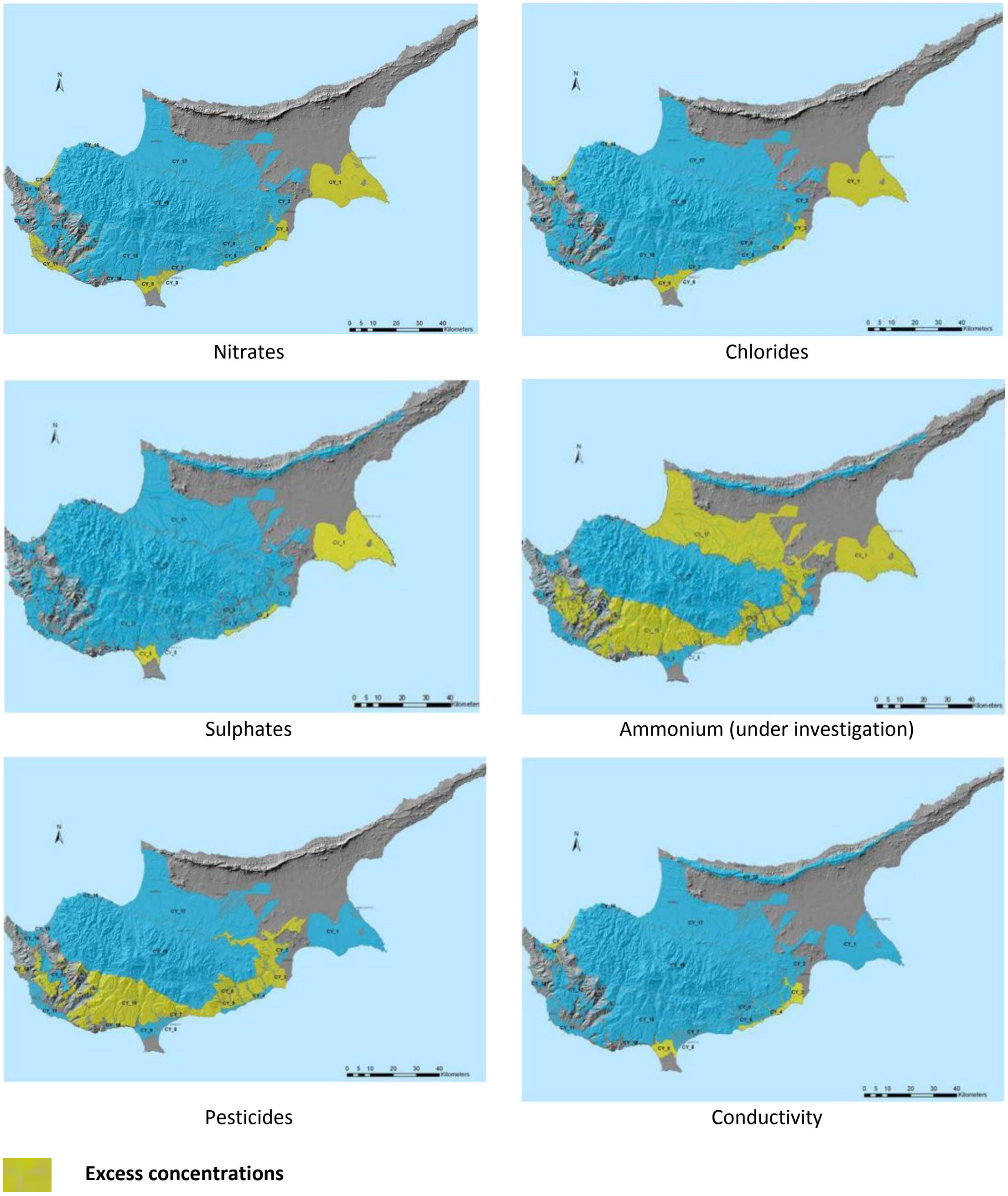


Figure 3-27: Excess values of selected parameters in the groundwater bodies of Cyprus

Source: WDD, 2011 – Annex VII

Furthermore, five (5) areas in Cyprus which drain into waters vulnerable to pollution from nitrogen nitrogen compounds have been declared as Vulnerable Nitrate Zones (VNZ), according to the

Directive 91/676/EEC. The five areas are the aquifers of Kokkinochoria, Kiti-Pervolia, Akrotiri, Paphos and Poli Chrisohous, and cover a total area of 419 km^2. By the end of 2010 another VNZ, VNZ, that of Orounda, has been delineated within the Western Mesaoria Groundwater Body. According to the available data, the total agricultural area that is located in vulnerable zones is is approximately 200 km^2. Approximately 80% of this land is irrigated with intensive agricultural agricultural practices taking place (GSD, 2008).

Figure 3-28 shows the designated Vulnerable Nitrate Zones and Sensitive Areas in Cyprus.

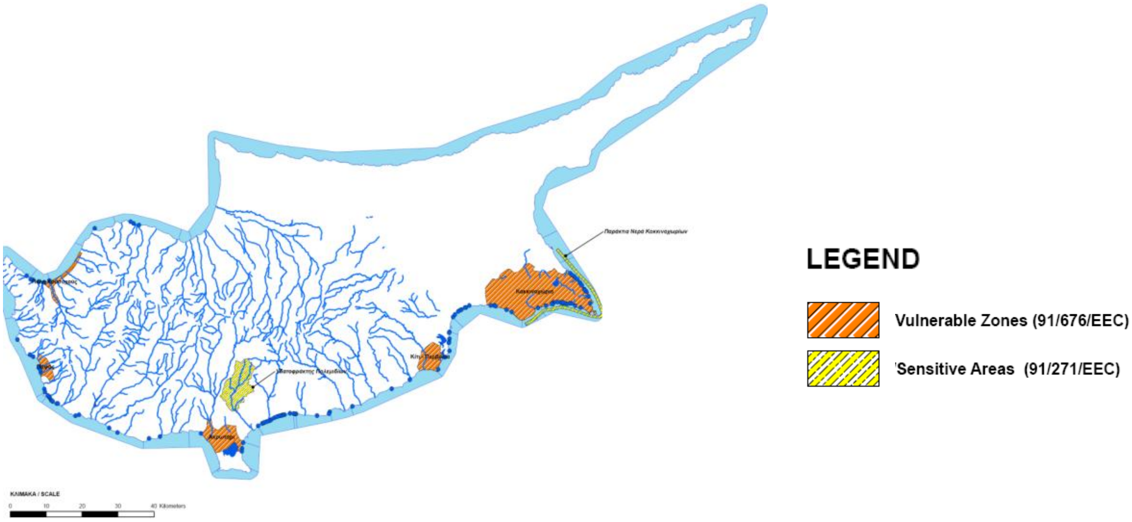


Figure 3-28: Vulnerable Nitrate Zones and Sensitive Areas in Cyprus

Source: WDD (9)

As regards to aquifer salinization, the aquifers located at the coasts – i.e. all major aquifers of Cyprus - are exposed to seawater intrusion and especially those located in low-lying areas (e.g. Larnaca). As a result, 12 out of 19 groundwater bodies in Cyprus have been exposed to saline intrusion while the coastal zones of several aquifers in Cyprus have been abandoned due to this phenomenon. It must also be noted that a potential sea-level rise would increase the amount of seawater intruded into freshwater aquifers.

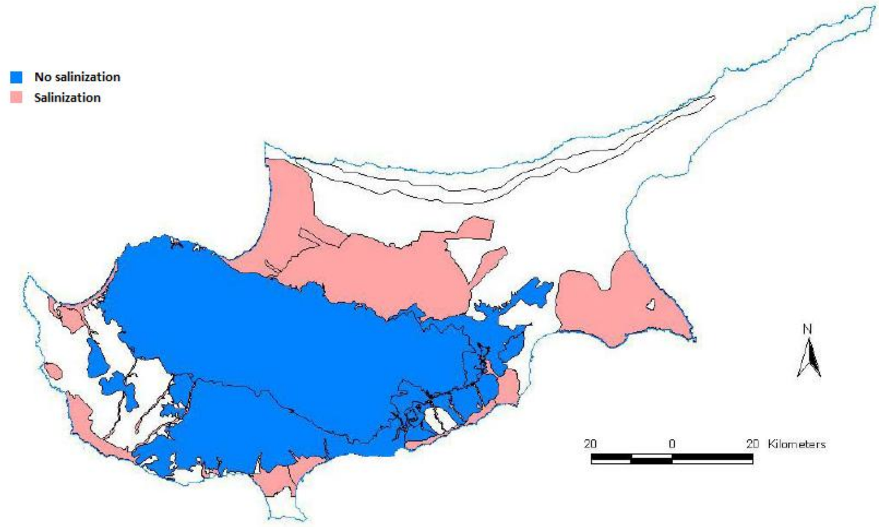


Figure 3-29: Salinization in the groundwater bodies of Cyprus

Source: WDD, 2008

To sum up, from the monitoring of the 19 groundwater bodies during the period 2000-2008, 8 groundwater bodies (42%) were characterized according to the Water Framework Directive as in bad qualitative condition, based on the results of chemical analysis in the salinity levels and/or the levels of pollutants present in the groundwater bodies (Table 3-10). In other words, the quality of groundwater bodies can be characterized as moderate to bad.

Table 3-10: Qualitative status of groundwater bodies

Groundwater body	Saline intrusion	High concentrations and/or excess	Condition
CY_1 Kokkinochoria	YES	Cl, SO_4, NO_3, NH_4,EC	BAD
CY_2 Aradippou Gypsum	NO		GOOD
CY_3 Kiti-Pervolia	YES	Cl, NO_3, EC, Pesticides	BAD
CY_4 Zigi-Softades	YES	Cl, SO_4, NO_3, EC	BAD
CY_5 Maroni Gypsum	NO	Pesticides	GOOD
CY_6 Mari-Calo Chorio & Chirokitia Sandstone	NO	As,NH_4,Pesticides	GOOD
CY_7 Germasogeia	YES		GOOD
CY_8 Limassol	YES	Cl, NO_3	BAD
CY_9 Akrotiri	YES	Cl, SO_4, NO_3,EC	BAD
CY_10 Paramali-Avdimou	YES		GOOD
CY_11 Paphos	YES	NO_3 locally	GOOD
CY_12 Letimvou-Giolou	NO	NH_4	BAD
CY_13 Pegeia	YES	Pesticides	GOOD
CY_14 Androlikou	NO	As	GOOD
CY_15 Chrisochou-Gialia	YES	Cl, NO_3, EC	BAD
CY_16 Pyrgos	YES	Cl, NO_3, NH_4	BAD
CY_17 Central and Western Mesaoria	YES	NH_4	GOOD
CY_18 Lefkara-Pachna	NO	As, NH_4	GOOD

Groundwater body	Saline intrusion	High concentrations and/or excess	Condition
CY_19 Troodos	NO		GOOD

Source: WDD, 2011a (Annex VII)

Taking into account the above, the exposure of the groundwater bodies in Cyprus to deterioration of their quality is characterized as **high to very high**.

3.4.2.2 Assessment of adaptive capacity

To protect freshwater from pollution, a wide range of legislation has been established in Europe. Most notably, the Water Framework Directive (WFD), which represents the single most important piece of EU legislation relating to the quality of fresh and coastal waters, aims to attain good ecological and chemical status by 2015. The Programme of Measures defined in the annual report of the Cyprus River Basin Management Plan (WDD, 2011a – Annex III) includes the establishment of regulations or basic measures that should be implemented in order to achieve the objectives set out for 2015.

3.4.2.2.1 Protected areas

In compliance with the Article 6 of the Water Framework Directive (WFD), Cyprus has created a register of all areas lying within its river basin district, which were considered requiring special protection under specific Community legislation for the protection of surface water and groundwater or for the conservation of habitats and species directly depending on water. The register includes all water bodies identified under Article 7 of the WFD and all protected areas covered by Annex IV of the WFD, namely:

i) Areas designated for the abstraction of water for human consumption in accordance with the Article 7 of the WFD;
ii) Areas designated to protect economically significant aquatic species (areas protected under Freshwater Fish Directive 78/659/EEC and Shellfish Directive 79/923/EEC);
iii) Water bodies designated as recreational waters, including areas designated as bathing waters, in accordance with the Directive 2006/7/EC;
iv) Areas designated as sensitive to nutrient pollution, including areas designated as vulnerable zones under the Nitrates Directive 91/676/EEC and areas designated as sensitive areas under the Urban Wastewater Treatment Directive 91/271/EEC;
v) Areas designated for the protection of habitats or species where maintaining or improving water status is important for their protection, including the sites of the "NATURA 2000" network, established under the Directives 92/43/EEC and 79/409/EEC.

Following, each of the aforementioned protected areas in Cyprus are presented.

(i) Areas designated for the abstraction of water for human consumption

The water resources used in Cyprus for drinking water abstraction are surface waters (dams-reservoirs) and groundwater. The protected areas under Article 7 of the WFD are presented in the following table.

Table 3-11: Protected water bodies used for drinking water abstraction

Category	Water body code	Protected area code
Surface water	CY_l-3-9_23_L4-HM	CY_PR-DRW_S-19
	CY_9-6-9_27_L4-HM	CY_PR-DRW_S-1
	CY_8-9-5_30_L4-HM	CY_PR-DRW_S-2
	CY_8-7-4_31_L4-HM	CY_PR-DRW_S-3
	CY_8-7-2_32_L4-HM	CY_PR-DRW_S-4
Groundwater	CY_1	CY_PR-DRW_GW-7
	CY_3	CY_PR-DRW_GW-8
	CY_6	CY_PR-DRW_GW-6
	CY_7	CY_PR-DRW_GW-9
	CY_9	CY_PR-DRW_GW-10
	CY_10	CY_PR-DRW_GW-11
	CY_11	CY_PR-DRW_GW-12
	CY_13	CY_PR-DRW_GW-13
	CY_14	CY_PR-DRW_GW-14
	CY_15	CY_PR-DRW_GW-15
	CY_16	CY_PR-DRW_GW-16
	CY_17	CY_PR-DRW_GW-17
	CY_19	CY_PR-DRW_GW-18

Source: WDD, 2011a – Annex I

For each of the protected areas presented in Table 3-11, in addition to meeting the objectives of Article 4 of the WFD for surface water bodies, Cyprus is engaged to ensure that, in the applied water treatment regime and in accordance with Community legislation, the resulting water will meet the requirements of Directive 80/778/EEC as amended by Directive 98/83/EC on the quality of water intended for human consumption.

(ii) Areas designated to protect economically significant aquatic species

No such areas have been identified in the river basin district of Cyprus.

(iii) Areas designated as recreational waters, including bathing waters

The harmonization of the national legislation of Cyprus with the Directives 76/160/EEC and 2006/7/EC on the management of bathing water quality was made by the Law on Water

Pollution Control 106(I)/2002, the Decree on Water Pollution Control (Quality of Bathing Water) 99/2000 and the Law on the management of bathing water quality 57(I)/2008. For the implementation of Directive 2006/7/EC, Cyprus designated in 2010, 113 bathing water areas.

These bathing water areas refer to almost all coastal water bodies of Cyprus (WDD, 2011a – Annex I).

(iv) Areas designated as sensitive to nutrient pollution, including vulnerable and sensitive areas

The Directive 91/676/EEC on the protection of waters against pollution caused by nitrates has been harmonized in the legislation of Cyprus with the Law on Water Pollution Control No. 106(I)/2002. For the protection of the Vulnerable Nitrate Zones identified in Cyprus, the Department of Agriculture of MANRE has established (a) a Code of Good Agricultural Practice as well as (b) an Action Programme to prevent or reduce water pollution from nitrates.

a) Code of Good Agricultural Practice

   The Code of Good Agricultural Practice which has been enacted in Cyprus by the Presidential Decree No. 263/2007 aims to reduce nitrate pollution from fertilizer use and livestock waste and the introduction of acceptable practices for the use of recycled water in irrigation and municipal sludge in agriculture that protect public health and the environment. However, the compliance with the guidelines of the code is prescriptive.

b) Action Programme to prevent or reduce water pollution from nitrates

   The implementation of the Action Programme to prevent or reduce pollution is already mandatory in the designated Nitrate Vulnerable Zones (NVZ). According to the action plan, farmers who use agricultural land located within nitrate vulnerable zones are required to comply with the relevant provisions of the Action Programme concerning the use and storage-transport of fertilizers, the use and storage of livestock waste / sludge, the monitoring and control, the irrigation methods as well as the chemical analyses.

For the protection of the two sensitive areas designated in Cyprus in compliance with the Directive 91/271/EEC on Urban Wastewater Treatment, a more stringent treatment of urban waste water entering collecting systems before discharge into the sensitive areas is required (WDD, 2011a – Annex I).

(v) Areas designated for the protection of habitats or species depending on water

These protected areas include the areas of Natura 2000 network, when the maintenance or improvement of water status is important for their protection, and the areas protected by national legislation. The Natura 2000 network consists of two types of areas, namely the Special Protection Areas (SPAs) for birds as defined in Directive 79/409/EEC, and the Sites of Community Importance (SCIs) as defined in Directive 92/43/EEC. The following table lists the areas of the Natura 2000 network, which include habitats or species directly depending on water (WDD, 2011a – Annex I).

Table 3-12: List of Natura 2000 areas in Cyprus depending on water

Code of protected area	NATURA 2000 code	Type
CY_PR-NP-01	CY2000002	SCI
CY_PR-NP-04	CY2000005	SCI
CY_PR-NP-06	CY2000007	SCI
CY_PR-NP-07	CY3000005	SPA/SCI
CY_PR-NP-08	CY3000006	SCI
CY_PR-NP-10	CY4000002	SCI
CY_PR-NP-11	CY4000003	SCI
CY_PR-NP-12	CY4000005	SCI
CY_PR-NP-13	CY4000006	SCI
CY_PR-NP-15	CY4000008	SCI
CY_PR-NP-16	CY4000009	SCI
CY_PR-NP-17	CY4000011	SCI
CY_PR-NP-19	CY5000001	SCI
CY_PR-NP-20	CY5000004	SPA/SCI
CY_PR-NP-22	CY5000006	SCI
CY_PR-NP-23	CY6000002	SPA/SCI
CY_PR-NP-24	CY2000010	SCI
CY_PR-NP-25	CY2000011	SCI
CY_PR-NP-26	CY2000012	SCI
CY_PR-NP-27	CY3000007	SPA
CY_PR-NP-28	CY3000008	SPA
CY_PR-NP-29	CY4000001	SCI
CY_PR-NP-30	CY4000007	SPA/SCI
CY_PR-NP-31	CY4000018	SPA
CY_PR-NP-32	CY4000019	SPA
CY_PR-NP-33	CY4000020	SPA
CY_PR-NP-34	CY4000021	SPA
CY_PR-NP-35	CY4000023	SPA
CY_PR-NP-36	CY5000005	SPA/SCI
CY_PR-NP-37	CY5000008	SPA
CY_PR-NP-38	CY5000009	SPA
CY_PR-NP-39	CY5000010	SPA
CY_PR-NP-40	CY6000007	SPA
CY_PR-NP-41	CY6000008	SPA
CY_PR-NP-42	CY6000010	SPA

Figure 3-30 depicts these Natura 2000 areas on the map of Cyprus.

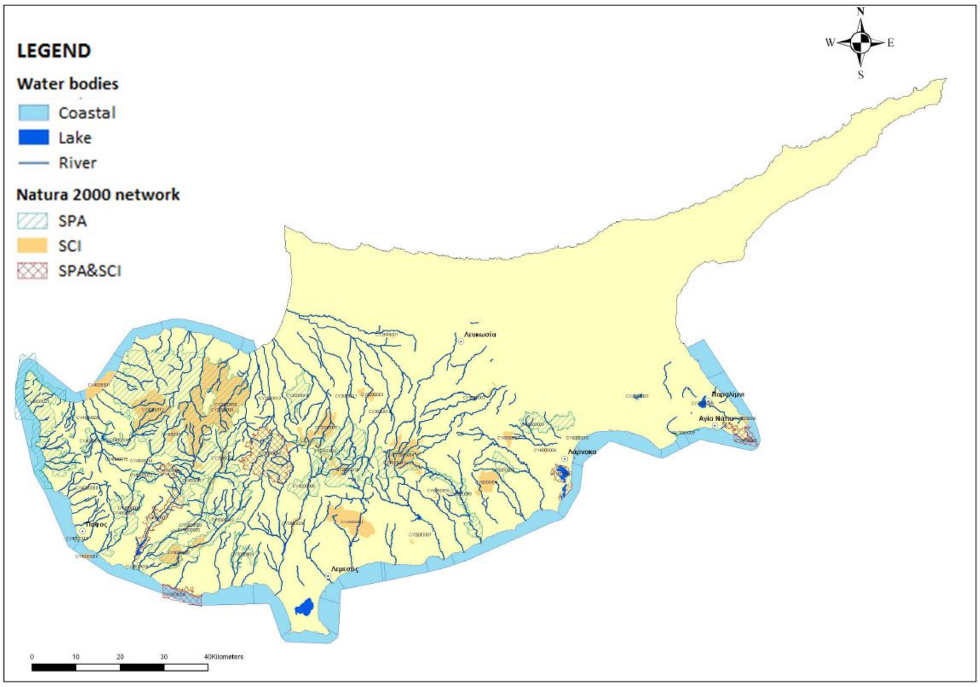


Figure 3-30: Map of Natura 2000 areas in Cyprus depending on water

As it can be seen, a considerable number of river, lake and coastal bodies in Cyprus are included in the Natura 2000 network.

3.4.2.2.2 Protection from point source discharges likely to cause pollution to water

The legislation of the Cypriot Government referred as "Water Pollution Control Laws 2002-2009" is the main tool with which all issues related to water pollution control from industrial and other activities are regulated. Article 6 of the Water Pollution Control Law (No. 106(I)/2002) prescribes that the discharge or disposal of any substances potential to cause pollution to water and soil is illegal without previous permission. Especially for installations included in the provisions of the IPPC Directive (large units with significant pollution potential), the Law No. 56(I)/2003 for Integrated Prevention and Pollution Control is applied.

Furthermore, aiming for compliance with the Urban Wastewater Treatment Directive (91/271/EEC) requirements, the wastewater collection and treatment infrastructure is being significantly expanded and upgraded. The capacity of the new Wastewater Treatment Plans in 2012 amounts to 59 Mm^3 per year and will reach up to 65 Mm^3 per year over the medium term (2015) and 85 Mm^3 for long-term (2025)(WDD, 2011a – Annex VII).

The pollution load to be treated is set to 675,000 population equivalent (p.e.) of which 80% are generated in urban agglomerations, which are the greater areas of Nicosia, Larnaca, Limassol and Paphos, and the municipalities of Ayia Napa and Paralimini. Existing sewage treatment plants have been extended recently. The Limassol-Amathus sewage treatment work has been enlarged from a treatment capacity of 70,000 p.e. to 272,000 p.e. and is now able to handle 40,000m^3 per day. Such upgrades correct the overload under which some plants have been working for years and eventually improve effluent quality (WDD, 2011a – Annex VII).

3.4.2.2.3 Protection of groundwater bodies from salinization

The water policy of Cyprus on the salinization of groundwater bodies, is based mainly on the prevention of seawater intrusion with the achievement of a positive balance between the abstractions and recharge, by setting proposed volumes of abstraction for each of its aquifers according to their quantitative condition. Furthermore, the measures foreseen for the achievement of a good chemical status of Cyprus groundwater bodies until 2015, in compliance with the Water Framework Directive, also contribute to this direction.

However, it must be noted that the rehabilitation of a groundwater body heavily affected by sea intrusion is a very slow process and sometimes almost impossible [6]. Consequently, the adaptive capacity of groundwater to salinization is characterized by low likelihood of reversibility or even irreversibility. Last but not least, it prerequisites the moratorium of abstractions. The time required may shorten by the application of artificial recharge with water rich in Ca^{2+} (Voudouris et al., 2005).

The implementation of these measures is expected to have a central role in improving qualitative water status. However, it is recognized that the hydrologic processes are such that it may be many years before protective measures actually lead to improvements in water quality and thus the adaptive capacity is characterized by delayed reversibility.

Pollution prevention and quality monitoring and restoration of groundwater are even more difficult than for surface waters mostly due to its inaccessibility. Its “hidden” character makes it difficult to adequately locate and quantitatively appreciate pollution sources and impacts, resulting in a lack of awareness and/or evidence regarding the extent of risks and pressures. In addition, groundwater usually reacts slower than surface water as processes (movement/pollution) usually take more time in groundwater and subsequently, recharge and remediation take much more time. Especially in slow moving groundwater, pollutants can persist indefinitely.

Consequently, it was estimated that the adaptive capacity of water quality to climate changes is **moderate** for the case of surface waters and **limited to moderate** for groundwaters.

[6] For the case of the sea intruded coastal aquifers in South Greece, this time was estimated to be some 180-600 years, given the complete cessation of abstractions (Voudouris et al., 2005).

3.4.3 Floods

3.4.3.1 Assessment of sensitivity and exposure

The distribution of floods according to their flood hazard (very low, low, moderate, high) in Cyprus in terms of adverse consequences for human health, environment, cultural heritage and economic activity for the period 1859-2011 is presented in Figure 3-31.

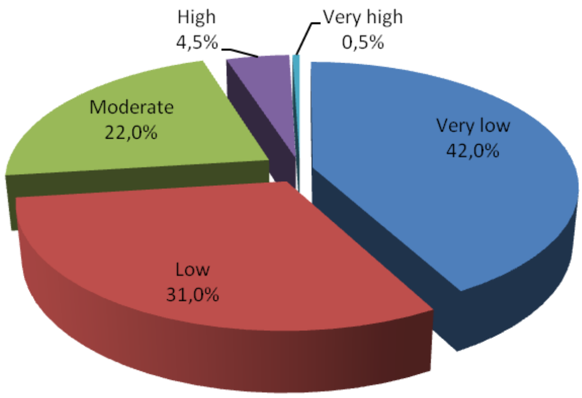


Figure 3-31: Hazard ranking of flooding events during the period 1859-2011

As it can be seen from the figure above, most of the flooding events in Cyprus are characterized as of "Very low" hazard (42%) and "Low" hazard (31%), while 4,5% of the events are characterized as of "High" hazard and only 0,5% as "Very high". Consequently, the sensitivity of Cyprus to floods is considered to be **limited**.

The damages caused by a flooding event with a given amount of precipitation depend on four factors: (i) the existing flood protection works, (ii) the degradation of the natural environment resulting in the increase of flooding volume and the decrease of the time of water flow, (iii) the intensity of human activity in flood risk areas (exposure) and (iv) the vulnerability of assets exposed to floods. The current vulnerability of Cyprus regarding flooding events will worsen with climate changes (WDD, 2011d).

According to WDD, the recorded floods in Cyprus for the period 1859-2011 are characterized as urban floods (37%), flash floods (20%), river or fluvial floods (16%), pluvial or ponding floods (13%), or a combination of the above (WDD, 2011d).

The urban centers of Larnaca, Limassol and Nicosia are exposed to flood risks mainly due to their dense structuring and the restriction of green space, the elimination of natural waterways for the construction of roads, the deficient or even absent stormwater drainage system and the covering of waterways and drain entrances with garbage.

In compliance with the Floods Directive 2007/60/EC, the Water Development Department of MANRE through its report "Preliminary Flood Risk Assessment" identified 19 areas around the island as "Areas with Potential Significant Flood Risk" (

Table 3-13). Those areas have a total length of 135 km and are distributed uniformly to all urban centers of Cyprus (no mountain areas included). They mainly refer to river parts that pass through built-up areas and are characterized by frequent and significant flash floods. In addition, the areas of Larnaca, Tremithos and Alambra are included in order to be taken into consideration in the next 5-year planning in case the projected flood protection works in Larnaca and Alabra and the existing protection zone of Tremithos river bed do not reduce the problem (WDD, 2011d).

Table 3-13: **Areas with potential significant flood risk in Cyprus**

Code	River name	Area	Type of flood
CY-APSFR**01**	Pedieos	From Politiko to the municipality of Nicosia	Flash flood
CY-APSFR**02**	Klimos	Engomi	Flash and urban flood
CY-APSFR**03**	Parapotamos Merika	Kokkinotrimithia	Flash flood
CY-APSFR**04**	Kalogeros	Strovolos, Latsia industrial zone	Flash flood
CY-APSFR**05**	Merikas, tributaries Koutis, Katouris	Paliometocho, Agioi Trimithias	Flash flood
CY-APSFR**06**	Almiros-Alikos	Dali's industrial zone	Flash flood
CY-APSFR**07**	Paralimni river and lake	Paralimni	Flash flood
CY-APSFR**08**	Yialias	Nisou, Pera Chorio, Dali	Flash flood
CY-APSFR**09**	Ormidias	Ormidia	Flash flood
CY-APSFR**10**	Archangelos Kamitsis and tributary	Aradippou-Livadia	Flash flood
CY-APSFR**11**	Kamaron	Kamares Larnakas	Flash flood
CY-APSFR**12**	Koshinos	Mesogi, Pafos, Chlorakas	Flash flood
CY-APSFR**13**	Limnarka	Pafos	Flash and urban flood
CY-APSFR**14**	Germasogia river	Germasogia	Flash flood
CY-APSFR**15**	Vathias river, Parapotamos Vathia	Mesa Geitonia, Agios Athanasios, Eastern Limassol	Flash and urban flood
CY-APSFR**16**	Garillis	Polemidia, Limassol	Flash and urban flood
CY-APSFR**17**	Argaki Marketou - Ipsonas	Ipsonas	Flash flood
CY-APSFR**18**	Komitis	Astromeritis	Flash flood
CY-APSFR**19**	Argaki Vasilikou	Pafos	Flash and urban flood
	Tremithos	Kiti-Perivolia	Flash flood
	Potamos Ammos	Alambra	Flash flood
	-	City of Larnaca	Urban flood

Source: WDD, 2011d

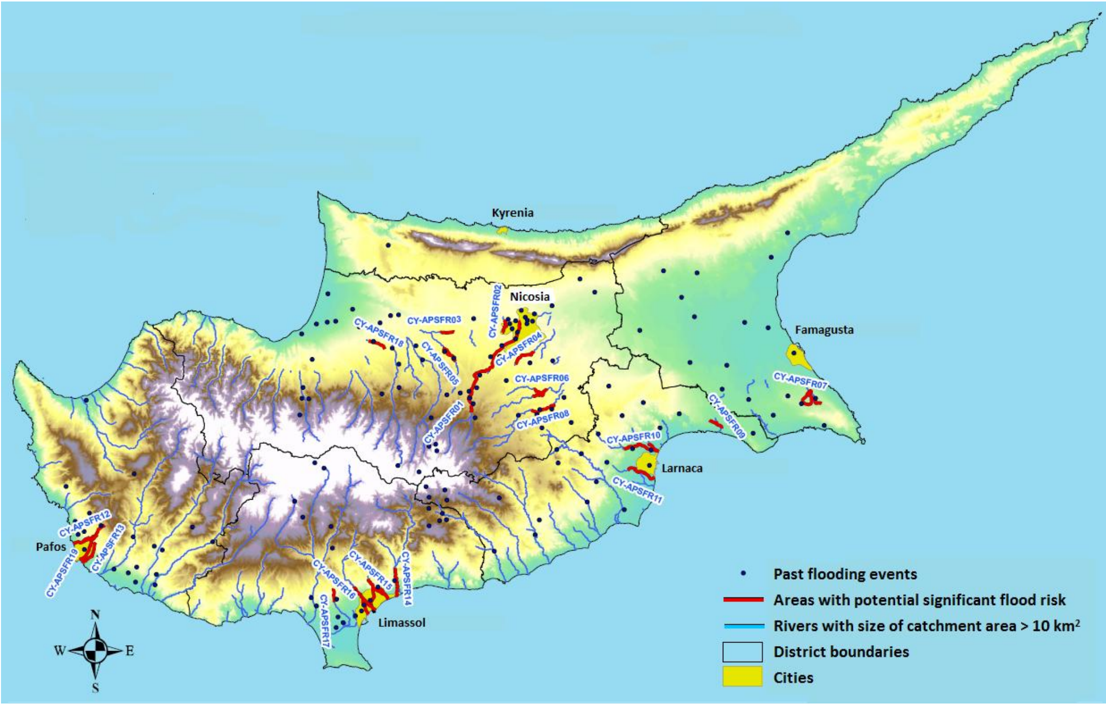


Figure 3-32: Areas with potential significant flood risk in Cyprus

Source: WDD (10)

As it can be seen from the map (Figure 3-32) the areas susceptible to floods are mainly the urban centers. Thus, Cyprus exposure to floods is characterized as **limited**.

3.4.3.2 Assessment of adaptive capacity

Cyprus' adaptive capacity to the increasing frequency and intensity of flooding events can be estimated by the existing flood protection works and the river protection zones as well as by the projected plans for the management of future flood risks.

The last two decades, a separate drainage system is being developed In Cyprus in order to collect stormwater. So far, the drainage network in the majority of the big urban centres of Cyprus has been completed. Furthermore, the Sewerage Board of Limassol-Amathus in cooperation with the five municipalities of the Greater Limassol area as well as the wider area of Paphos began the implementation of Sustainable Urban Drainage Systems (SUDS). Sustainable Urban Drainage Systems (SUDS) are used for the reduction of flood risks and the exploitation of stormwater for aquifer recharge. For example, in Limassol the construction of four stormwater retention ponds is promoted, with a total capacity of 200,000 m^3. The first pond has already been formed in part of the flood protection work west of the port. The second pond has been scheduled as part of the flood protection works in the area west of the A'Industrial Zone of Limassol. In the Paralimni lake there is channel system which controls the water outflow from the lake (flood protection work), recharges the aquifer and sends water to dam. Moreover, the area of Paphos has been identified as a suitable area for the implementation of SUDS while for the case of Larnaca due to its topography, no suitable measures have been identified. In Nicosia, no such initiatives have been implemented yet (WDD, 2009).

The Law 70(I)2010 on the Flood Risk Assessment, Management and Preparedness, which harmonizes the Floods Directive 2007/60/EC with the Cypriot legislative framework states that Flood Hazard maps and Flood Risk maps must be prepared by the end of 2013, while Flood Risk Management Plans must be prepared by the end of 2015. As it was mentioned in previous section of this report, the WDD has already implement preparatory steps in conformity with the EU Directive for the Preliminary Assessment of Flood Risks and has identified 19 areas in Cyprus as areas for which Potential Significant Flood Risks exist or might be considered likely to occur. It is expected that the identification of those areas will motivate the relevant authorities in order to implement all the necessary flood protection works in the framework of the Flood Risk Management Plans.

Considering the above, the adaptive capacity of Cyprus to floods is estimated as **moderate**.

3.4.4 Droughts

3.4.4.1 Assessment of sensitivity and exposure

Cyprus with very limited water resources is vulnerable to droughts as it has developed most of all its natural water resources, with most of its aquifers depleted, and no perennial rivers. During the period 1969-2010, Cyprus has suffered from a number of severe droughts. In all cases, the events initiated as meteorological droughts but very quickly they developed into hydrological droughts since Cyprus has no perennial rivers and the rivers length is very short. As shown in Table 3-14, drought phenomena in Cyprus are very frequent, persistent and severe since reduced precipitation in relation to the average precipitation of 1961-1990 (503 mm) was observed for up to 8 consecutive years with the deficit reaching 640 mm. In view of the possible future increases in drought frequency not only in the Mediterranean region but across Europe as well as a consequence of climate change, Cyprus vulnerability to drought may increase.

Table 3-14: Consecutive years with precipitation below normal (<503 mm) in Cyprus, 1969-2010

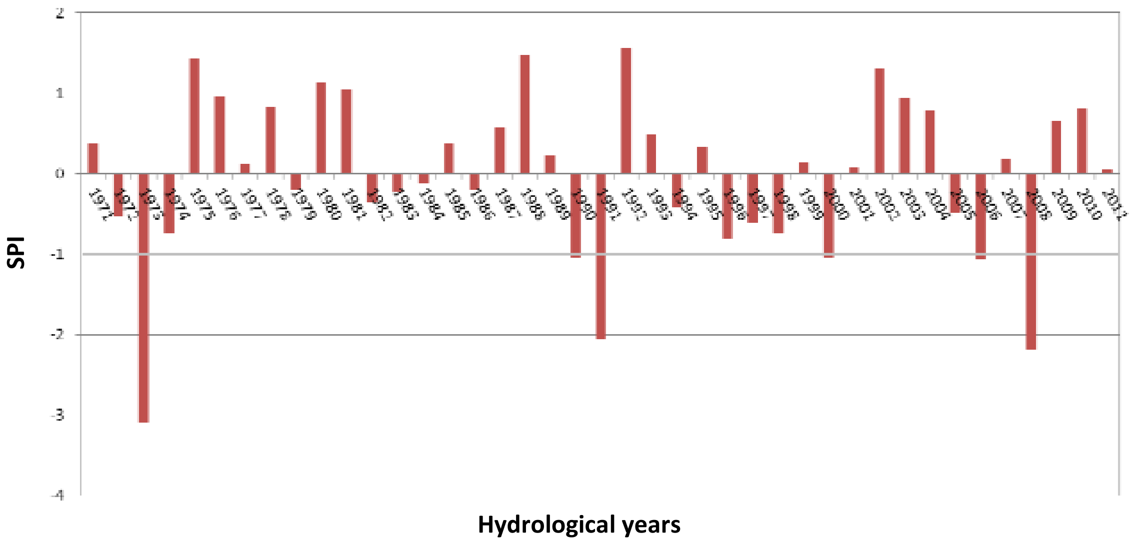
Hydrological year	Mean precipitation (mm)	Difference from normal (mm)	Remarks
1969/70	398,4	-104,6	5 consecutive years Deficit: 608,5 mm
1970/71	497,9	-5,1	
1971/72	408,3	-94,7	
1972/73	212,7	-290,3	
1973/74	389,2	-113,8	
1981/82	424,7	-78,3	5 consecutive years Deficit: 271,6 mm
1982/83	437,5	-65,5	
1983/84	448,3	-54,7	
1984/85	497,9	-5,1	
1985/86	435,0	-68,0	
1988/89	480,5	-22,5	3 consecutive years Deficit: 384,1 mm
1989/90	362,5	-140,5	
1990/91	281,9	-221,1	
1993/94	416,7	-86,3	8 consecutive years Deficit: 640,6 mm
1994/95	493,0	-10,0	
1995/96	383,0	-120,0	
1996/97	399,0	-104,0	
1997/98	387,8	-115,2	
1998/99	473,0	-30,0	
1999/00	363,2	-139,8	
2000/01	467,7	-35,3	
2004/05	412,1	-90,9	4 consecutive years Deficit: 488,2 mm
2005/06	360,1	-142,9	
2006/07	479,3	-23,7	
2007/08	272,3	-230,7	

Source: Meteorological Service of Cyprus

During the extended drought period of 2004/05–2007/08, lower than average rainfall resulted in minimal flow of water in the dams. By the beginning of 2008 water reserves in dams were almost depleted, giving rise to the need to adopt costly temporary measures in order to meet consumers needs for drinking water during the summer of 2008 (e.g. import of drinking water with tankers from Greece, imposition of severe cuts in water supply by 30 % to households and no water allocated for agricultural purposes), which resulted in the dramatic reduction of farmers' yields. Households were supplied with water for around 12 hours a day, three times a week (EEA, 2010).

According to the categorization of hydrological years made by the Meteorological Service of Cyprus based on the normal precipitation of the period 1961-90 (503mm), 29% of the years during the period 1901-2010 are characterized as 'severe drought' (6%), 'drought' (12%) and 'below normal' (11%) (MSC).

The Standardized Precipitation Index (SPI), which provides a quantitative definition of drought (McKee et al., 1993), was computed for the 12 month time scale (October – September) for the period 1970/71 - 2010/2011. As can be seen in Figure 3-33, these past 40 years have been marked by three extreme drought years, with an SPI below -2 (1972/73, 1990/91, 2007/08). There were also three years of moderate droughts (1989/90, 1999/00, 2005/06 and 12 years of mild drought.



SPI Value	Characterization
0 - (-0,99)	Mild drought
(-1) - (-1,49)	Moderate drought
(-1,5) - (-1,99)	Severe drought
< (-2)	Extreme drought

Figure 3-33: **Standard Precipitation Index for the government controlled area of Cyprus (1901/02-2010/11)**

Source*:* Bruggeman et al., 2011

Taking into consideration the abovementioned indicators, it can be concluded that the exposure of Cyprus to droughts is **very high**.

In order to estimate sensitivity to droughts in Cyprus, the **Sensitivity to Desertification Index** (SDI) is used. This index has been used in the project “Desertification Information System to Support National Action Programmes in the Mediterranean” (DISMED), where the EEA is involved, in order to map sensitivity on desertification and drought. The index was obtained from the geometrical average of three indexes of the soil quality, climate and vegetation.

Although Cyprus was not included in this study, a study was assigned to I.A.C.O. Ltd by the Department of Environment of MANRE in 2007 in order to designate the sensitive areas to desertification in Cyprus. The designation of the areas threatened by desertification, under the concept of Environmentally Sensitive Areas (ESA), was made by analyzing factors and processes leading to desertification based on available data in Cyprus and international references. For the detailed designation of the ESAs, accepted indices for the evaluation of potential desertification have been used (MEDALUS, European Commission) after adjustment to the Cyprus conditions.

Employing the definition for the areas sensitive to desertification (FAO-UNESCO) by using the bioclimatic index P/ET_0 , where P is the mean annual rainfall and ET_0 the potential evapotranspiration, showed that in Cyprus there are two climatic zones that are considered as sensitive to desertification; the semi-arid area which extends over the larger part of the island and the arid sub-humid area which covers the slopes of the Troodos range to the higher parts of the Kyrenia range.

No area was identified as being below the threshold limit signifying desertification while the areas that do not face any desertification problem (values >0,65) are only 1,5% located at the highest parts of the Troodos Mountains. This area is enveloped by a sub-humid area (4,5%) of a reduced sensitivity. The largest part of the remaining areas (91%), are characterized as semi arid with an increased sensitivity while 3% are immediately threatened. Figure 3-34 presents the designation of the ESAs in Cyprus.

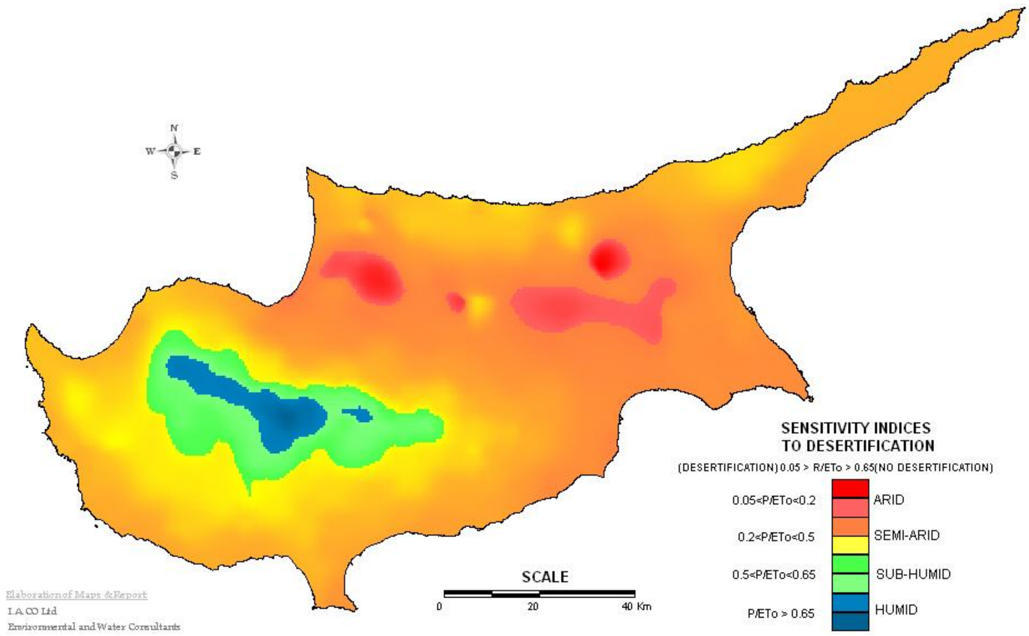


Figure 3-34: Environmentally Sensitive Areas to Desertification

Source: I.A.C.O. Ltd, 2007

Given that 91% of the total area of Cyprus was characterized as critical or sensitive, Cyprus' sensitivity to drought is considered to be **very high**.

3.4.4.2 Assessment of adaptive capacity

Drought management is an essential element of water resources policy and strategies in EU but especially in drought prone areas, such as Cyprus. Following up the recent drought management of 2008 in Cyprus, it was found that adaptive strategies were limited. Dealing with the shortfall of water resources consisted of corrective and emergency measures with the implementation of drought mitigation plans. Decision makers have reacted to drought episodes mainly through a crisis-management approach by declaring a national or regional drought emergency programme to alleviate drought impacts. Nevertheless, nothing can be done to reduce the recurrence of drought events in a region. Therefore, drought management should not be regarded as managing a temporary crisis. Rather, focus must be given on developing comprehensive, long-term drought preparedness policies and plans of actions that place emphasis on monitoring and managing emerging stress conditions and other hazards associated with climate variability in order to significantly reduce the risks and vulnerabilities to extreme weather events (WDD, 2011a – Annex VIII).

According to the European Commission (EC, 2008) Drought Management Plans (DMP) should be prepared in advance before they are needed, based on relevant country specific legislation and after careful studies are carried out concerning the characterization of the drought in the basin, its effect and the mitigation measures. The main objective of drought management plans is to minimize the adverse impacts on the economy, social life and environment when drought appears. This general objective can be developed through a series of specific objectives that might include:

- Guarantee water availability in sufficient quantities to meet essential human needs to ensure population's health and life.
- Avoid or minimize negative drought impacts on the status of water bodies, especially on ecological flows and quantitative status for groundwater and in particular, in case of prolonged drought, as stated in article 4.6. of the WFD.
- Minimize negative effects on economic activities, according to the priority given to established uses in the River Basin Management Plans, in the linked plans and strategies (e.g. land use planning).

The Water Development Department of Cyprus has elaborated a Drought Management Plan in 2010 (WDD, 2011a – Annex VIII) in order to address these issues. The DMP of Cyprus structures upon the EU policy on drought management and is closely linked with the Government Water Policy which is based on the Framework Directive (WFD) criteria and objectives. The main elements of the Cyprus DMP are:

- An early warning system based on hydrological indicators
- A correlation of indicators with thresholds for different drought stages to trigger action
- A set of phase-specific measures to achieve objectives

The main index for each hydrologic region is selected to be the corresponding 12 month SPI based on which the alert status is decided. The 12 month runoff index is used as a check on the SPI, since there is no past implementation of this system in Cyprus. In a case when the runoff index is more adverse than the SPI, a decision shall be taken by the responsible authorities. The alert level status for the River Basin Area (whole of Cyprus) is given by the worst alert level status of the different Hydrologic Regions. However, the drought management measures will apply only in the hydrologic regions it is required. As for the other indices, the wet period runoff index provides an early warning tool for the operators, since its calculation can provide an indication of drought earlier than the 12 month SPI. Finally, the storage capacity index concerns the alert level in relation to the Southern Conveyor and Paphos water projects and is directly related to the allowed abstractions (WDD, 2011a – Annex VIII).

The actions against drought according to the level of alert may include the notification of responsible operators, raising awareness for sustainable water use, notification of users for consumption reduction, increase in desalinated water production, intensive controls of abstractions and leakages, limits to the abstractions from dams, releases from dams only for river ecosystem protection. In Table 3-15 the actions against drought corresponding to certain stand-by levels are presented.

Table 3-15: Correspondence of Alert Level and Actions

Alert Level	Actions
Mild	Notification of responsible operators. Notification of users for increased consumption awareness. Increase of water supply served from desalination plants. Abstractions from large projects according to the storage capacity index.
Moderate	Notification of responsible operators. Notification of users for increased consumption awareness. Increase of water supply served from desalination plants. Status announcement and intensive public notification program. Intensive controls for restrictions to uncontrollable abstractions and pumping, as well as for wastage limitations. Abstractions from large projects according to the storage capacity index.
High	Notification of responsible operators. Notification of users for consumption reduction. Increase of water supply served from desalination plants. Status announcement and intensive public notification program. Intensive controls for restrictions to uncontrollable abstractions and pumping, as well as for wastage limitations. Abstractions from large projects, according to the storage capacity index, but not more than those that correspond to the action “significant shortage”. Monthly regime index calculation and measures received relevant to the upstream abstractions, if this is necessary (index smaller than 5%).
Extremely High	Notification of responsible operators. Notification of users for consumption reduction. Maximization of desalination plants production, when excess quantities storage is possible. Status announcement and intensive public notification program. Intensive controls for restrictions to uncontrollable abstractions and pumping, as well as for wasting limitations. Abstractions from large projects, according to the storage capacity index, but not more than those that correspond to the action “extreme shortage”. Monthly regime index calculation and measures received relevant to the upstream abstractions, if this is necessary (index smaller than 5%). The environmental releases from dams will be limited to the absolutely necessary for the river ecosystem protection and not for groundwater body recharge.

Source: WDD, 2011a – Annex VIII

According to the EU policy on drought (EC, 2008), a DMP should provide a dynamic framework for an ongoing set of actions to prepare for, and effectively respond to drought, including periodic reviews of the achievements and priorities, readjustment of goals, means and resources, as well as strengthening institutional arrangements, planning, and policy-making mechanisms for drought mitigation. Effective information, early warning systems and drought risk maps are the foundation for effective drought policies and plans, as well as effective networking and coordination between competent authorities in water management at different levels. In addition to an effective early warning system, the drought management strategy should include sufficient capacity for contingency planning before the onset of drought, and appropriate policies to reduce vulnerability and increase resilience to drought. When working towards a long-term drought management strategy, it is necessary to establish the institutional capacity to assess the frequency, severity and localisation of droughts and their various effects and impacts on crops, livestock, the environment and specific drought impacts on populations. This is rather a complex process that requires increased capacity, strong institutional structure as well as active administrative and public involvement.

Cyprus has considerably increased its adaptive capacity in coping with drought by adopting the EU guidelines on water and drought management. However, the Cyprus DMP and its Water Policy have recently implemented and have yet to be tested to prove their efficiency in achieving the abovementioned goals. For these reasons, Cyprus current adaptive capacity to droughts is considered **moderate**.

3.4.5 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of water resources to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of water resources against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for the water sector in Cyprus are summarized in Table 3-16.

Table 3-16: Overall vulnerability assessment of the water resources in Cyprus to climate changes

Impact		Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Water availability	for domestic water supply	Very high (7)	Very high (7)	High (5)	Limited to Moderate (2)
	for irrigation	Very high (7)	Very high (7)	Limited to Moderate (2)	High (5)
Water quality	of surface water bodies	Moderate to High (4)	Limited to Moderate (2)	Moderate (3)	None (-0.2)
	of groundwater bodies	High to Very high (6)	High to Very high (6)	Limited to Moderate (2)	Moderate to High (4)
Floods		Moderate (3)	Moderate to High (4)	Moderate (3)	Limited (0.5)
Droughts		Very high (7)	Very high (7)	Limited to Moderate (2)	High (5)

As it can be seen from the table above, the current key vulnerabilities of water resources in Cyprus related to climate changes, are the water availability for irrigation, droughts and groundwater quality, as well as in a lesser degree the water availability for domestic water supply while floods are considered of limited vulnerability. In specific, water availability for irrigation consists a key vulnerability of the sector to climate changes since the available water resources for irrigation are limited while water demand for agriculture is large and inspite of the various measures undertaken mainly in government level, water demand for irrigation is not met most of the times. Droughts present an equally important vulnerability for the water sector, since droughts are a common phenomenon in Cyprus with detrimental effects for water availability in the island, while the measures that are being taken manage only to avoid the worst effects but not to eliminate all adverse consequences. Groundwater quality is the next vulnerability priority for water resources since the majority of groundwater bodies are already in a bad qualitative situation while their rehabilitation is very slow. Water availability for domestic water supply is also substantially affected by climate changes since freshwater resources most of the times were not sufficient for satisfying demand for drinking water. However, the Government of Cyprus has undertaken a series of drastic measures for the increase in water supply, such as the commissioning of desalination plants, thus relieving the island from such a pressure.

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4 SOIL RESOURCES

The thin layer of soil covering the earth's surface represents the difference between survival and extinction for most terrestrial life.

(Doran & Parkin, 1994)

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Abbreviations and Acronyms

CIAM	Centre for Integrated Assessment Modelling
CLIMSOIL	Climate Change Soil Carbon
DOA	Department of Agriculture
DoE	Department of Environment
DoF	Department of Forests
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
FAO	Food and Agriculture Organization
ies	Institute for Environment and Sustainability
JRC	Joint Research Centre
MANRE	Ministry of Agriculture, Natural Resources and Environment, Republic of Cyprus
NRCS	Natural Resource Conservation Service
PWP	Permanent Wilting Point
RDP	Rural Development Programme
SSSA	Soil Science Society of America
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
UNEP	United Nations Environment Programme
USDA	United States Department of Agriculture
NRCS	Natural Resources Conservation Service
WDD	Water Development Department
WHO	World Health Organization

4.1 Climate change and soil resources

Soil is, certainly, one of the most important variables, as it is necessary for the comprehension of the landscape evolution, erosion and sedimentation, environmental change, natural hazards and in general subsurface geology. In addition, soil provides a variety of requirements for plants -such as shelter, moisture storage and a supply of nutrients- and thus for animal life too. The common denominator of all soil problems is soil degradation. This issue has affected many countries of the world, as more than 1.2 billion hectares in 1990 were areas of severe concern for soil degradation (World Resources Institute, 1990) (Figure 4-1).

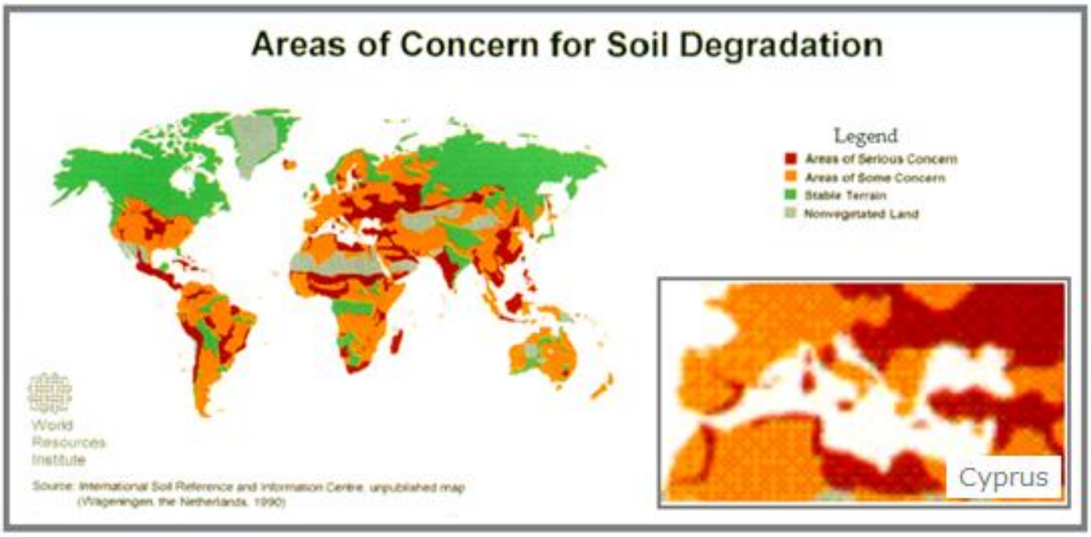

Figure 4-1: Areas of concern for soil degradation

Source:World Resources Institute, 1990

Climate change could change or endanger ecosystems and the many goods and services they provide, mainly due to the strong influence over dryland vegetation type, biomass and diversity (WMO, 2005). Many soil properties and processes will be influenced by alteration of spatial and temporal patterns in temperature, rainfall, solar radiation and winds enhancing the existing problem of soil degradation.

Despite the significance of the problem, there is still no concerted effort at global level for the systematic monitoring of the impacts of different climatic factors on land degradation in different regions and for different classes of land degradation (WMO, 2005).

Cyprus due to its geographical position in the eastern part of the Mediterranean Sea, bears all the characteristics of a semi-arid climate and some of the deficits of the global climate change. During the latest decades, remarkably low precipitation has been recorded, rating the island in the second most threatened zone in terms of land degradation (Figure 4-1).

4.2 Baseline situation

4.2.1 Status of soil resources in Cyprus

The island of Cyprus is characterized by two mountains regions (the limestone range of Kyrenia and the Troodos range), a central plain of Mesaoria and the coastal plains. Slopes in excess of 18% and 12% cover 10% and 22% of the island, respectively (Figure 4-2). Furthermore, slope aspect of SW and SE trending cover nearly 45% of the island (Figure 4-3).

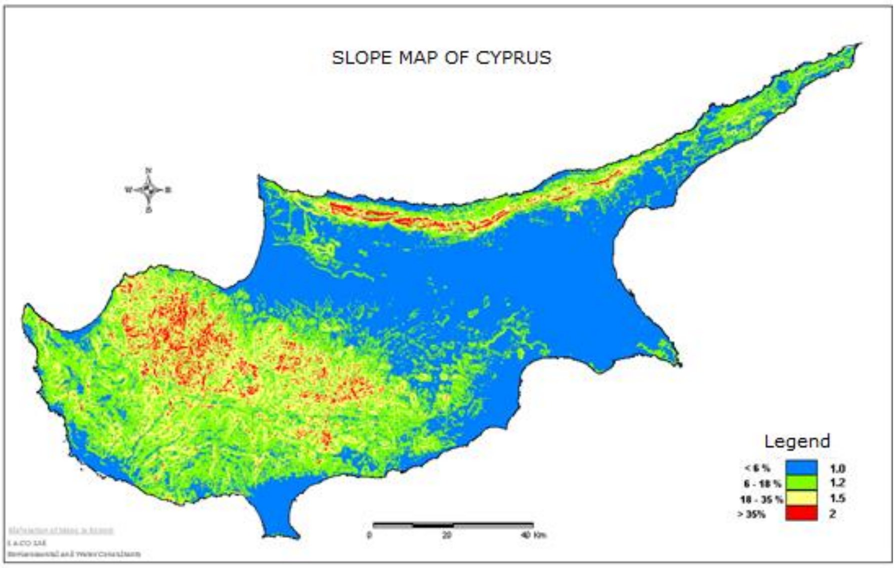

Figure 4-2: Slope map of Cyprus

Source: National Action Plan for Combating the Desertification (I.A.CO Ltd, 2007)

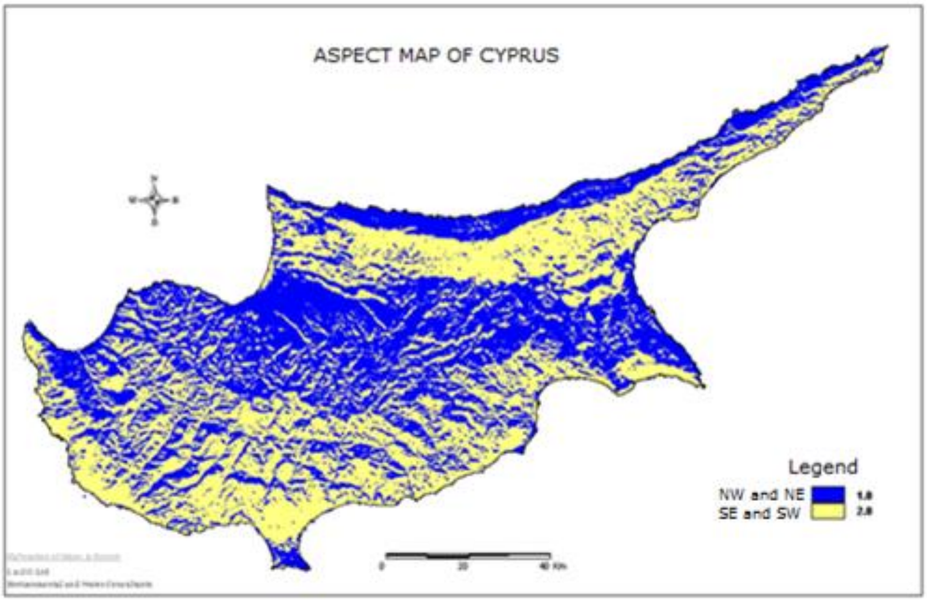

Figure 4-3: Aspect map of Cyprus

Source: National Action Plan for Combating the Desertification (I.A.CO Ltd, 2007)

The climate of Cyprus is semi-arid in general, and almost sub-humid around Troodos Mountains (Figure 4-4).

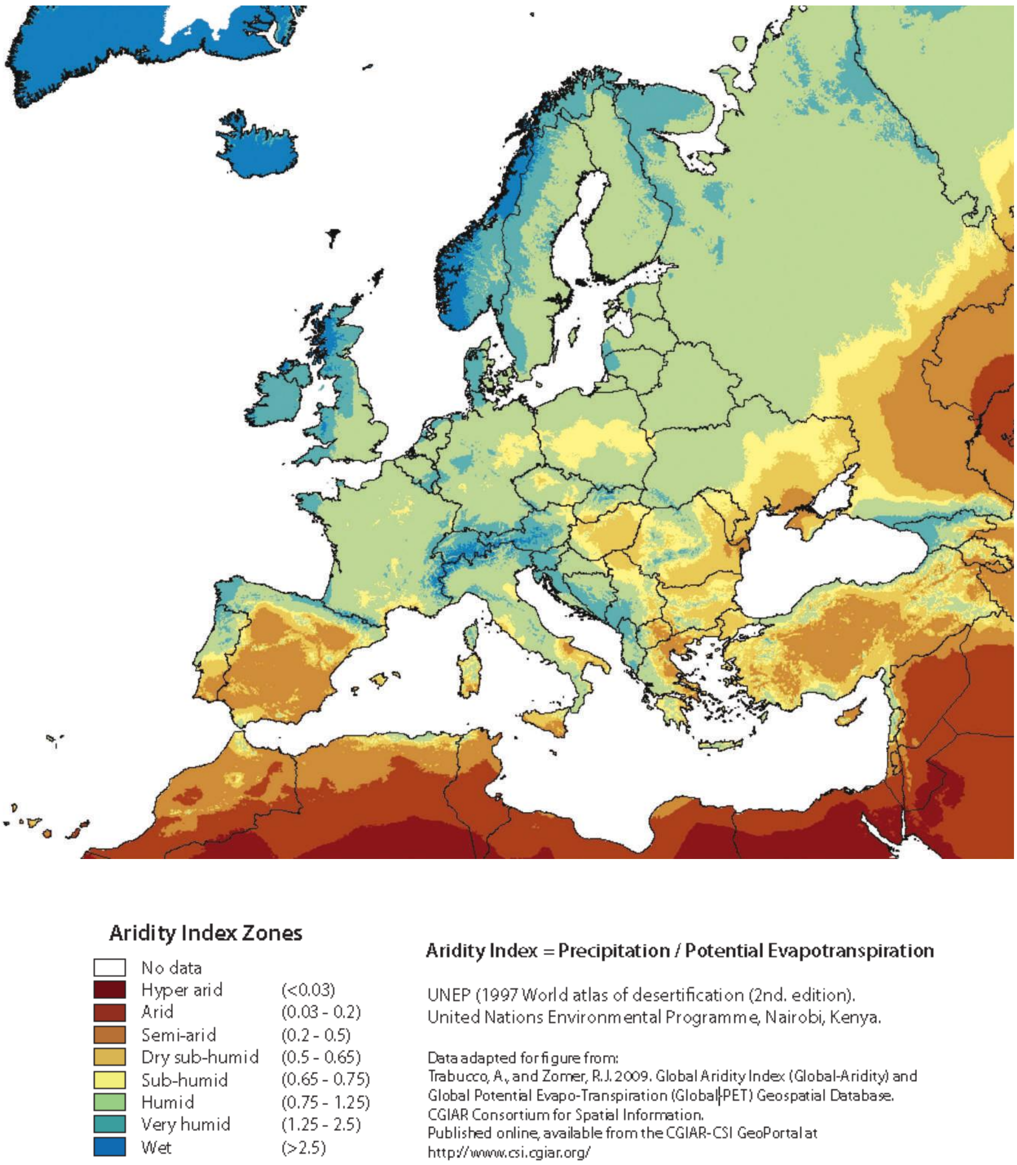

Figure 4-4: European Aridity Index map

Source: European Atlas of Soil Biodiversity (JRS European Comission, ies Institute for Environment and Sustainability, 2010)

The geological background of the island of Cyprus (Figure 4-5) is formed by three geological zones: a) the ophiolithic complex of the Troodos Mountain range and its extension under the Mesaoria, b) the Mamonia zone and c) the Kyrenia Mountain range consisting mainly of allocthonous formations. In between these lie the autochtonous sedimentary rocks (Republic of Cyprus, Geological Survey Department; I.A.CO Ltd, 2007).

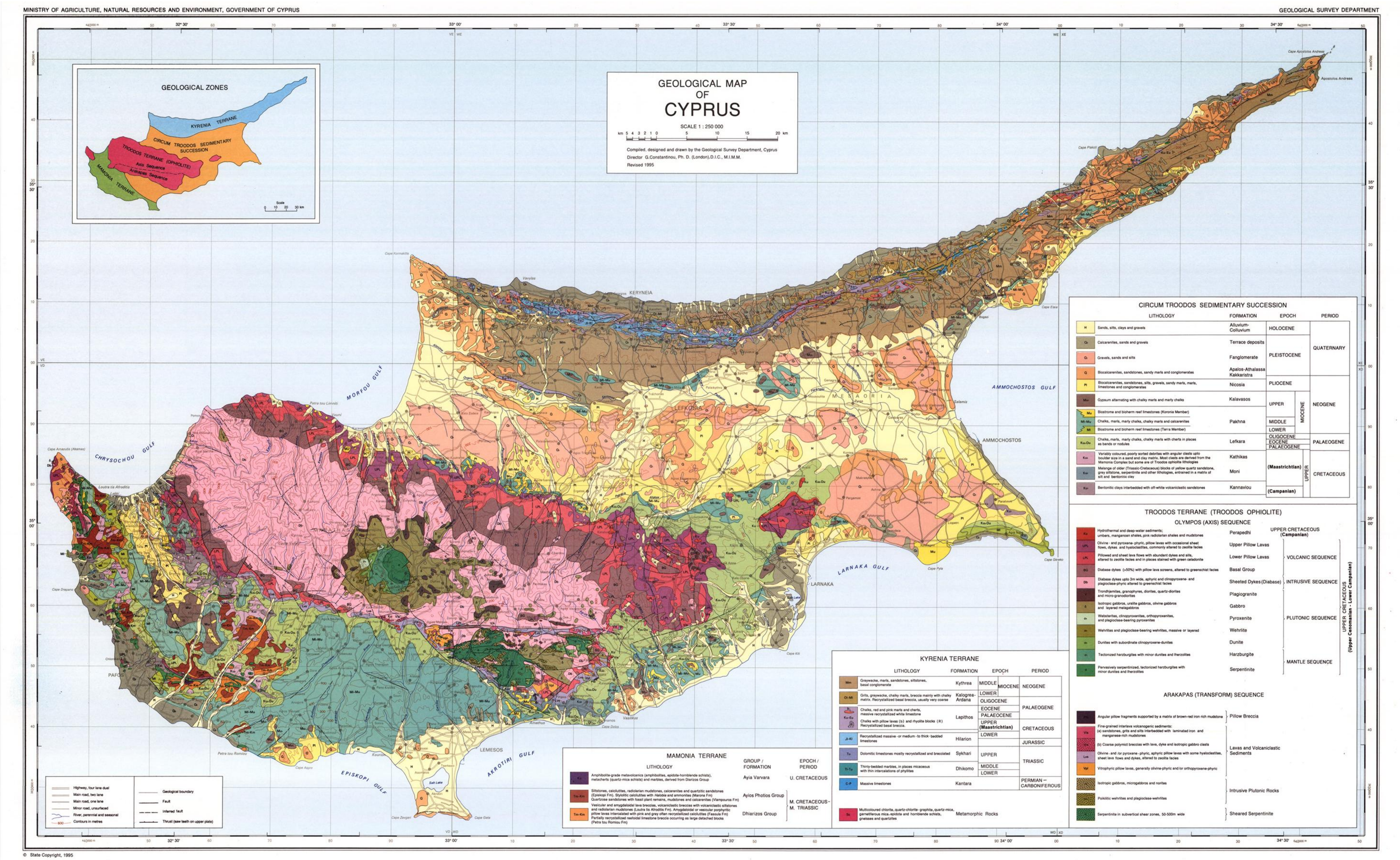

Figure 4-5: Geological map of Cyprus

Source: Geological Survey Department

There have been extensive researches for the identification-determination of the physical and chemical soil properties and the classification of the various soil types for the island of Cyprus since 1957 (Hadjiparaskevas). According to the latest system for soil mapping, the dominant soil types in Cyprus are leptosols, regosols, cambisols and associated soil groups, as shown in Table 4-1 and Figure 4-6.

Table 4-1 : Main soil groups in Cyprus based on the FAO (1998) classification. Data from Hadjiparaskevas(2008).

Soil order	Sub-order	Characteristics
Lithosols	Calcaric Eutric	Limited in depth by continuous coherent and hard rock within 10 cm of the surface.
Fluvisols	Calcaric Eutric	Recent alluvial deposits, having no diagnostic horizons other than an Ochric A or a histic H horizon.
Regosols	Calcaric Eutric	Uncosolidated material, having no diagnostic horizons other than an ochric A horizon.
Rendzinas		Mollic horizon immediately overlying extremely calcareous material.
Solonchaks	Gleyic Orthic	High salinity within 125 cm of the surface (EC > 15 mmhos).
Solonetz		Natric B-horizon.
Ventisols		40% or more clay in all horizons, developing wide cracks from the soil surface downwards.
Cambisols	Ventic Calcaric Calcic Eutric Chromic	Cambic B-horizon and no diagnostic horizon other than an ochric or an umbric A horizon, a calcic or a gypsic horizon.
Luvisols	Vertic Calcic Chromic	Argillic B-horizon.

Source: Biochemical atlas of Cyprus (Cohen & Rutherford, 2011)

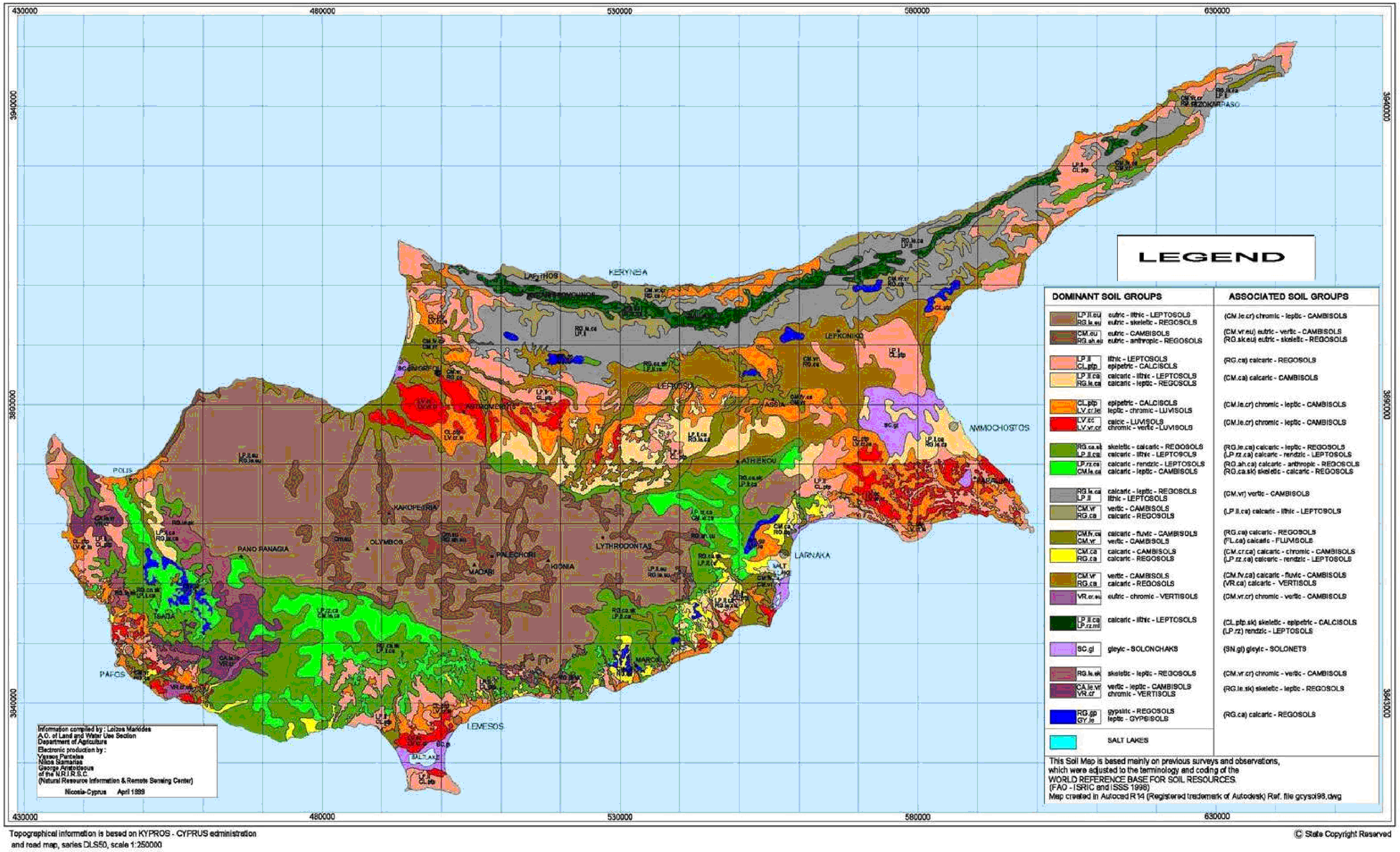

Figure 4-6: Soil map of Cyprus

Source: Hadjiparaskevas, Soil Survey and Monitoring in Cyprus, 2005

As shown from the table (Table 4-1) and figures (Figure 4-5 and Figure 4-6) above, the soil characteristics vary across different regions of Cyprus (MANRE)*:

- valley and coastal areas
- western and central Mesaoria
- southeastern Mesaoria
- Troodos igneous massif
- Episkopi-Akrotiri-Garyllis-Yermasoyia
- Pissouri-Paramali Area
- Paphos
- Gypsum Kalavasos Aquifer Area
- Moni-Pareklishia Area and
- Minor or non Aquifer Areas

Some of the soil characteristics of these areas are presented next (MANRE).

- **Valley and coastal areas***

Most of the whole coastal area is occupied by soils developed on alluvium. Alluvial soils in the narrow valleys alongside the rivers are shallow to deep medium texture and overlie loose gravels. Porosity and drainage conditions are therefore, excellent. Alluvial soils on the coastal plain in the Kiti-Perivolia-Dromolaxia area are level to gently sloping, deep to very deep medium textured (sandy loam to clay loam) with excellent porosity and drainage conditions. Calcium carbonate content varies between 15-25%, pH is alkaline (8,0–8,5) and organic matter content in the surface soil is low (1,5%). Alluvial soils in the coastal area of Zygi-Maroni-Psematismenos are level to gently sloping, very deep, light grey brown and rather heavy with clay loam to clay texture. Structure on the surface soil in moderately developed granular to blocky becoming less pronounced below. Porosity and drainage conditions are satisfactory. The calcium carbonate content is high ranging from 45–55%, pH is alkaline and organic matter of the surface soil around 1,5%. Alluvial soils are interrupted in places by red heavy soils developed on fanglomerate, as can be found in the Mazotos-Maroni area.

Soils in the Chrysochou valley are usually level to gently sloping, medium textured overlying loose igneous gravels at some depth. Porosity and drainage conditions are, therefore, excellent. The calcium carbonate content is around 30 – 40%, pH is alkaline (8,0 – 8,5) and organic matter of the surface soil low (1,0–1,5%). Most of the soils in the line from Polis to Nea Dimmata are usually moderately sloping, very deep, medium textured and gravelly with very good porosity and excellent drainage conditions. They do not contain calcium carbonate, pH is around 7,5–8,0 and organic matter content is low (1,0–1,5%).

- **Western and Central Mesaoria***

In the narrow valleys of Gialias, Pediaeos, Akaki and Peristerona, the rivers are bordered by gently sloping alluvial soils. Close to the riverbank, these soils are shallow and gravelly

* Email communication with Mr Christos Hadjantonis from MANRE.

overlying loose igneous gravels. Away from the riverbank, soils become deeper but always overlying loose igneous gravels at some depth. These soils usually have medium to moderately fine texture (sandy loam to clay loam) and porosity and drainage conditions are excellent. The calcium carbonate content varies from 10–20%, pH is alkaline (8,0–5,5) and organic matter, is low (1,5–2,0%). Such soils are characteristic of the Dhali-Potamia area, Pano Deftera and Avlona-Katokopia.

The Akaki and Peristerona rivers are tributaries of the Serrachis river which is the main contributor of sediments to the Morphou alluvial plain. Red fine textured A/B/Cca level to gently sloping soils have formed over fanglomerate. Horizon A has a clay loam to clay texture with a well-developed fine and medium blocky structure, friable consistency and favourable porosity conditions. The calcium carbonate content is low varying from 0-5%, pH is alkaline (7,8-8,3) and organic matter 1-2%. Horizon Bt is redder and heavier, with a clay content of around 50%. Structure is moderately developed prismatic breaking to angular blocky. The soil becomes sticky when wet and hard when dry. Porosity and drainage conditions are less favorable compared to horizon A. The calcium carbonate content is usually low but in some cases accumulated at depth to form a B(Ca) or C(Ca) horizon rich in calcium carbonate. Red soils may overly soft, or hardened “havara” or even thin “kavkalla” crust at a depth of 30-100cm as is the case in the Kokkinotrimithia-Palaiometocho-Akaki area, or they may overly loose permeable of conglomerated impermeable gravels as in the Peristerona-Astromeristiw-Katokopia area. On the “Nicosia” formation, rather shallow poor very calcareous soils have formed with rather undulating topography. Such soils are usually left uncultivated or used for rainfed agriculture, mainly cereals.

- **Sounth Eastern Mesaoria (Kokkinochoria)**[*]

Shallow to deep red developed A/Bt/Bca, level to gently sloping soils are predominantly developed on the fanglomerate deposits of the area. Surface soil (horizon A) is friable and usually has a clay loam t clay texture (35-45% clay), a well developed blocky structure and satisfactory porosity and aeration conditions. The calcium carbonate content varies from 0-3% and the organic matter content is low, not usually exceeding 1%.

Subsoil (horizon B) is redder and heavier than horizon A with clay texture (clay content 50-60%) and a moderate prismatic structure breaking easily to angular blocky. Porosity conditions are less favorable than in horizon A; the soil is sticky and plastic when wet, and hard when dry. The organic matter content is even lower than that of horizon B, and the calcium carbonate content usually varies from 0-3%. In some cases, however, calcium carbonate accumulates in the lower part of the horizon forming a B(Ca) sub-horizon rich in calcium carbonate.

Red soils in this area normally rest on very calcareous deposits (“havara”) hardened in many occasions to form a thin lime crust called “kavkalla” especially when the soil is shallow. The presence of “kavkalla” at some depth below the surface is supposed to inhibit the normal drainage of excess water and salts to the deeper layers.

[*] Email communication with Mr Christos Hadjantonis from MANRE.

- **Troodos Igneous Massif***

The basic common characteristics of soils in the area are as follows:

-They are usually shallow, stony and eroded with steep and sharp slopes. In small alluvial-colluvial valleys and in the lower areas, deeper soils with gentler slopes are encountered.

-They do not contain free calcium carbonate. The pH is usually neutral to slightly alkaline (7,0-8,o).

-Soils are generally immature medium textured without any development of horizons. In the forest areas where permanent vegetation exists organic matter accumulates in the top 10cm of the soil reaching 3-4%. In areas with no permanent vegetation the organic matter content of the surface soil is much lower.

-Soils have excellent porosity and aeration conditions and drainage excess water through the pores is very fast.

-Due to steep slopes, most of these soils require leveling with the use of heavy machinery before the can be used for agricultural purposes. Gabbro and lava rocks are soft and easily weatherable giving a soil ready to accept plants, in a very short time after leveling.

- **Episkopi-Akrotiri-Garyllis-Yermasoyia**[*]

In parts of Zakaki-Trachoni, Asomatos-Ypsonas and Polemidia, red developed A/BtCCa soils occur. These are fine textured soils throughout with generally strongly developed blocky or prismatic structure. They are predominantly moderately deep to deep with calcium carbonate contents ranging from 10-30%, usually overlying extremely calcareous rather soft “havara” sediments (60-70% calcium carbonate). In some cases, however, especially where “havara” is lying closer to the surface, a very hard thin lime horizontal crust has formed on top of a hardened “havara” called “kavkalla”. This is said to be impermeable or partly impermeable, inhibiting normal leaching of excess water and salts.

In considerable parts of Polemidia, Ypsonas and Episkopi, deep to very deep A/B/C soils were formed on relatively older alluvial deposits. Profile development structure and color are less pronounced in these soils, compared to red ones. Texture is usually fine (clay loam to clay) and calcium carbonate content varies between 20-45% throughout profile.

In the narrow Yermasoyia and Erimni valleys, as well as in the broader Episkopi valley near the river Kouris bank, recent alluvial soils predominate, overlying loose gravels at varying depths and thus creating excellent drainage conditions. Soils are usually of medium texture (Sandy loam, sandy clay loam to clay loam) with calcium carbonate content varying from 20-40%.

Soils in the area have a rather low to moderate organic content at the surface, ranging from 1-2%. In the subsoil layers this is even lower. In the case of citrus orchards, the surface organic matter below the canopy reaches 2,5%.

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[*] Email communication with Mr Christos Hadjantonis from MANRE.

- **Pissouri-Paralimni Area***

Soils in the Paralimni-Avdimou and Pissouri small valleys are very deep, light greish brown, and very calcareous (50-60% calcium carbonate content). Soil texture in Paralimni valley is medium (sandy clay loam to clay loam) while in the Avdimou and Pissouri soils are heavier (clay loam to clay).

Soil pH is alkaline (8.0-8.5) and organic matter is around 1.5-2.0%. Porosity and drainage conditions are generally satisfactory. Soils on the "Nicosia" geological formation are shallow to moderately deep and fine textured, overlying marly and sandy marly horizontal layers. They are very calcareous (40-60% calcium carbonate) alkaline and have low organic matter (1,0-1,5%).

- **Paphos***

Soils in the coastal area from Kouklia to Paphos have developed on either alluvium or on terrace deposits, and are normally deep to very deep fine textured with clay content in the surface soil varying from 35-45% and in the subsoil from 45-55%. They are generally heavy and compact A/B/C soils with rather poor structural development and in most cased do not possess very favorable porosity and drainage conditions. When wet, soils become very plastic and sticky and on drying they become very hard. Calcium carbonate content varies from 10-30% and the pH is alkaline (8,0-8,5). Organic matter in the surface soil is around 1,5-2,0% becoming lower in the subsoil.

Soils in the coastal area north to Paphos are more variable in depth and origin. They are usually developed on old terrace deposits but also on more recent alluvium as in the Potima area close to Mavrocolympos river. Soils may be shallow to deep, brown, reddish brown or even red overlying "havara" or hard "kavkalla" or river gravels. Most of the soils in the area maintain a clay loam to clay texture with a clay content varying from 35 to 45%, and a large proportion of coarse material. They are rich in calcium carbonate which reaches 50-60% in many cases. The pH is always alkaline (8,0-8,5) and organic matter is low (1,0-1,5%).

- **Gypsum (Kalavasos) Aquifer Area***

Soils are predominantly shallow to moderately deep, extremely calcareous (60-70% calcium carbonate) with slopes usually varying between 10 to 40%, overlying alternating layers of gypsum and chalk. The presence of exposed rock outcrops is very common. Deeper gently to moderately sloping soils are present in small colluvial valleys.

- **Moni-Pareklishia Area***

Soils on lava rocks are usually shallow to moderately deep, medium textures, overlying the parent rock, which is usually easily weatherable and penetrable by roots and water. Soils in the small valleys are normally deeper and finer in texture. All soils in the area are free from calcium carbonate, pH is around 7,5-8,0 and organic matter is low (1%).

* Email communication with Mr Christos Hadjantonis from MANRE.

- **Minor or non Aquifer Areas***

Soils in the hilly areas are, in their great majority, shallow to moderately deep (30-60cm), stony, medium to fine textured with slopes usually varying from 10-40%. They rest on alternating layers of limestone, chalks, marls, chalky marls and other lithologies which usually have vertical fractures which may be penetrated by roots and water. In the small valleys in between the hills there are deeper soils with finer texture and smoother slopes. In the lower areas, more extensive valleys are present, with very deep fine textured soils and usually gentle slopes.

All soils in the area, except those on the "Mamonia" geological formation, are highly calcareous (50-70% calcium carbonate content), and therefore whitish in color. The organic matter content of the surface soil varies from 1,5-2,0% and the pH is alkaline throughout the soil profile (8,0-8,5).

4.2.2 Pressures

Land degradation involves two interlocking, complex systems (World Meteorological Organization, 2005): the natural ecosystem (climate, ecology) and the human social system (society, culture, technology) which cause additional pressure on soil resources. These features are necessary to be mentioned in order to present the current situation in Cyprus. A list of factors retrieved from a relevant study of the United Nations University (2005) and adjusted for the case of Cyprus, is presented in the following table (Table 4-2):

Table 4-2 : List of factors contributing to land degradation

Categories	Factors
Climate aspects	Variability (uneven geographic distribution and temporality of precipitation)
	Reduction of frequency of precipitation
	Increase of frequency of rainfall's intensity
	Increase of temperature (and certain variables of temperature)
	Heat-wave
	Reduction of snow cover in Troodos
	Increase of evapotranspiration (contributes to the intensification of soil drying)
	Other climate aspects
Ecological aspects	Temperature limitations
	Water variability (drought and heavy rains)
	Unfavorable climate (incl. variability)
	Geological instability (e.g. periodic seismic activity, geological erosion and sediment loads)
	Topographic difficulties (steepness, roughness)
	Restricted soil fertility and susceptibility

Categories	Factors
	Vulnerability of land resources
	Climate change
	Plant and animal diseases
	Natural hazard deposition
	Environmental pollution (e.g. waste and construction, pollution form quarrying)
	Deforestation
	Other ecological aspects
Socio-cultural aspects	Outmigration, manpower availability
	Missing of undapted land use regulations
	Land ownership and privatization
	Tradition and culture
	Education and knowledge on resource use
	Attitude and awareness towards land resources
	Abandonment of the rural areas and overexploitation of the left agricultural areas
	Overgrazing
	Geopolitical pressures between countries (more water drillings in the southern part of Cyprus after 1974)
	Other socio-cultural aspects
Economic aspects	Limited economic performance of agriculture
	Restricted market access, economic isolation
	Energy dependence on oil inputs
	Other economic aspects
Technological aspects	Lack of land use alternatives and arable land
	Poor land use (e.g. urban sprawl, commercial development, vehicle off-roading)
	Absence of crop rotation and fallow periods
	Overuse of fertilizers
	Too many water drillings and near the seashore
	High land use intensity (e.g. overgrazing, poor pasture management, poorly regulated hunting, poor tourism development in coastal and mountain areas)
	Unadapted irrigation practices (e.g. poor soil and water management for irrigated and rainfed crop production)
	Other technological aspects

The above mentioned pressures (Table 4-2) in combination with several factors of climate change deteriorate some environmental phenomena or create new more complicated conditions for the soils of Cyprus. Considering the above as well as the study conducted by I.A.CO. (2007), the additional pressures on soil resources of Cyprus as a result of several activities are listed below:

- Eutrophication due to contaminated waters.
- Degradation of soil productivity due to desertification (I.A.CO Ltd, 2007).

- Changes in plant species distribution due overexploitation and contamination of surface and ground water (DoE, 2000), affecting soil biodiversity.
- Changes in forest plant species distribution in the abandoned parts of the unprotected state forests, affecting soil organic matter.
- Soil retrogression and changes in soil biodiversity due to overgrazing.
- Increased carbon sequestration due to the reforestation of croplands.
- Loss of organic carbon because of the tilling of the land.
- Soil changes due to changes of the land use.
- Erosion of soils due to the abandonment of the rural areas and the overexploitation of the left agricultural areas.
- Degradation of soils near the seashore due to tourism development.
- Land degradation of cities due to urbanization (Figure 4-7 and Figure 4-8).
- Increased erosion of soils due to the the aging of the rural population, and the abandonment of the rural areas and the traditional agricultural activities.
- Soil salinization from the many water drillings due to increased water need in the centre and south of the island after the forced movement of people in 1974 (Turkish invasion).

The above factors are used additionally, in order to assess the vulnerability of soil resources due to climatic changes in a more integrated perspective.

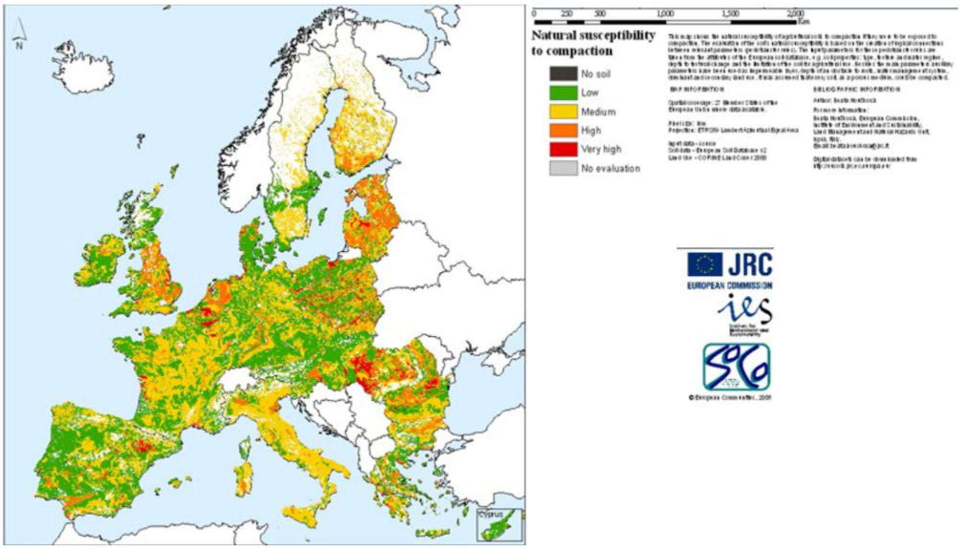


Figure 4-7: The natural susceptibility of soils to compaction

Source: European Soil Portal (JRC, 2012)

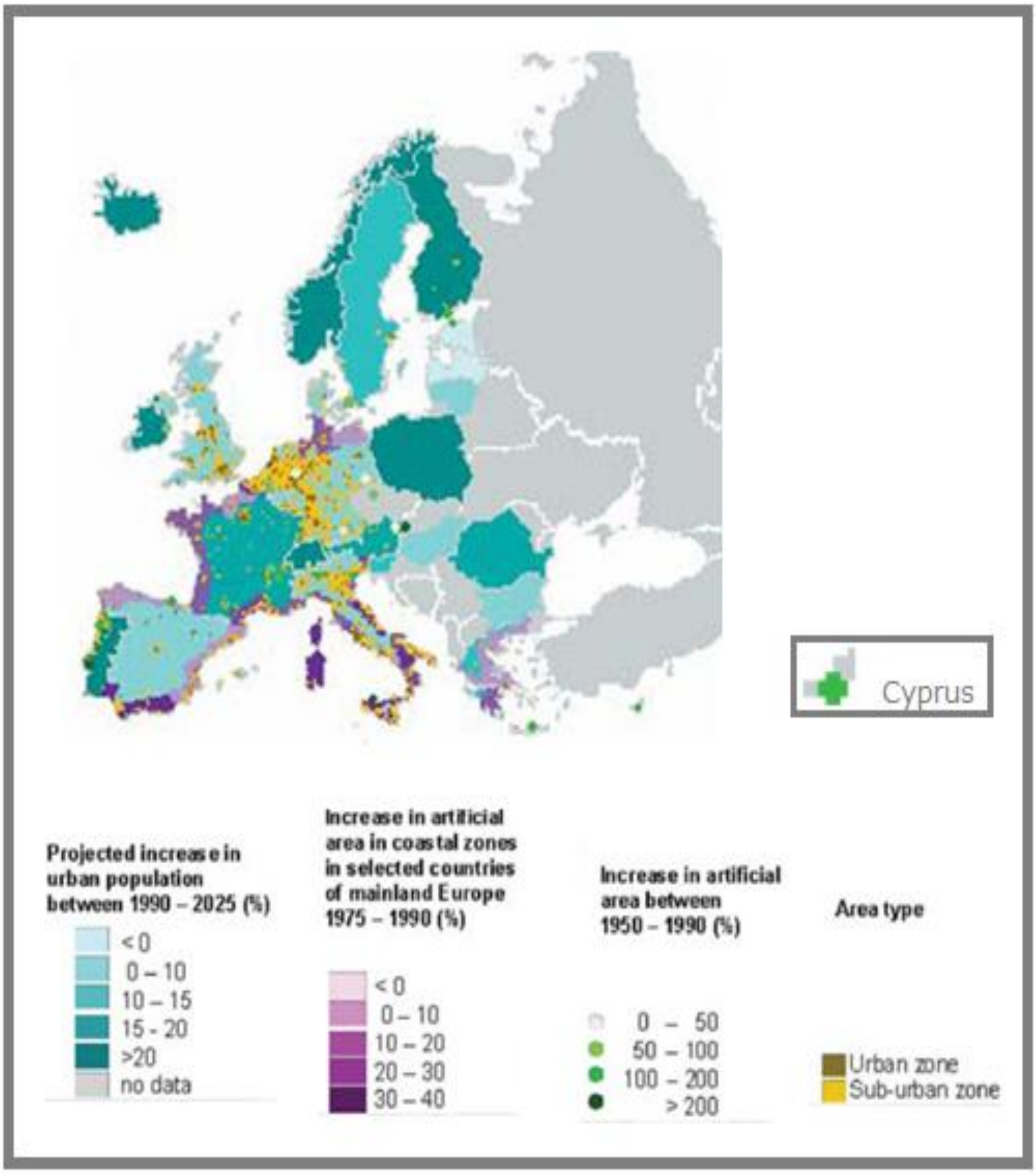


Figure 4-8: Probable problem areas of soil sealing in Europe

Source: European Soil Portal (JRC, 2012)

4.3 Impact assessment

Alterations in the mean and extreme (maximum, minimum) values of factors of climate (rainfall, temperature, atmospheric emissions, wind) cause changes in soils through complicated physical procedures (directly and indirectly). The general correlations between the observed climate changes in Cyprus and the impacts on soil resources of temperate climates[1] are listed in the following table (Table 4-3).

Table 4-3 : Relationship between observed climate changes and impacts on the soil resources sector

Observed climate change in Cyprus	Impacts on soil resources in temperate climates
Decreased rainfall & increased temperature	– Some small chemical effects on soils, due to the increased evapotranspiration (Brinkman & Sombroek, 1996). – Negative effect on soil organic matter due to temperature rise (Brinkman & Sombroek, 1996). – Greater organic matter supply from vegetation or crops growing more vigorously because of the combined phenomena of the higher photosynthesis, the greater potential evapotranspiration and the higher water-use efficiency in a high-CO_2 atmosphere (Brinkman & Sombroek, 1996). – Mineralogical change of the stability of iron oxide haematite over the dominant goethite, leading to a decrease of the intensity and amount of phosphate fixation and finally to the reddening of presently brown soils (Brinkman & Sombroek, 1996; Buol et al., 1990).
Droughts	– Decrease of soil moisture due to the decreased rates of groundwater recharge. – Reduction of crop yields (soil fertility) (Moore, 2005). – Removal of certain nutrients from soil (Moore, 2005). – Increased soil erosion. – Decrease in soil respiration (Vallejo et al., 2005). – Reduction of soil organic carbon (Vallejo et al., 2005). – Reduction of litter inputs with the uncertainty associated with this process (Vallejo et al., 2005). – Soil salinization (Vallejo et al., 2005).
Heavy and/or intense precipitation events	– Flooding and water logging of soil. – Landslides (Paul & Kimble). – Flooded upland soils cause oxygen depletion or reducing conditions, which may in turn affect the chemistry of the soil-water system and, consequently, soil aggregation (SSSA, 2009). – Deterioration of soil quality by making it more prone to erosion due to the raindrop impact (Proffitt et al., 1993). – Increased soil erosion due to poor vegetation.
Sea level rise	– Salinization of coastal soils (minor effect). – Changes in the geomorphology of the seashore.
Increased	– Increase of growth rates and water use efficiency of natural vegetation, leading to increased night time respiration and shorter growth cycles which

[1] The table was made in order to present all the possible dimensions of the observed climate changes in Cyprus. The reason for presenting impacts on soil resources from other regions of the Mediterranean (similar to the climatic conditions of Cyprus) in this table is the lack of data regarding certain features which have not yet been examined by the competent bodies of the island. In the following chapters, we analyze the characteristics for which data are available.

Observed climate change in Cyprus	Impacts on soil resources in temperate climates
atmospheric CO_2	can cause unproductive periods in the soils of agro-ecosystems (Brinkman & Sombroek, 1996). – Increased productivity is accompanied by more litter, greater root activity and increased microbial activity. Microbial activity combined with higher concentrations of CO_2 lead to accelerated rates of plant nutrient release and inevitably to the increase of the quantity of plant nutrients cycling through soil organisms (Brinkman & Sombroek, 1996). – Greater microbial activity in combination with higher soil temperatures produce greater amounts of polysaccharides and other stabilizers leading to the increase of the "stable" soil organic matter content and stimulates further the microbial activity (macrofauna, earthworms), improving infiltration rate and bypass flow by the greater number of stable biopores. These phenomena increase the resilience of soil against water erosion and loss of soil fertility. In addition, the increased proportion of bypass flow also decreases the nutrient loss by leaching during periods with excess rainfall. – Despite the positive effects for the soil plant system, temporarily problems can be caused by the competition of plants for nutrients. This temporary effect is responsible for the impact of plant response to elevated CO_2 (Brinkman & Sombroek, 1996).
Changes in fire regimes (increased number of wildfires)	Burnt areas are more prone to erosion. An untouched area by fire near a burnt one is more prone to soil particle displacement by landslides. Soil hydrophobicity (Moss & Green, 1987). Degradation of soil biodiversity. Loss of organic matter.

The complexity of the impacts of climate change on soil resources is obvious, and as a result there are several indicators which can be used in order to present the soil condition of an area. For the purpose of this assessment, the impacts of climate change presented in

Table 3-1 are grouped in the following impact categories (Table 4-4) and assessed in the sections that follow.

Table 4-4: List of selected impacts

	Selected impacts	Source
1	Soil erosion (by wind and/or rain water	Indicator established by the Commission of the European Communities (Commission of the European Community , 2006)
2	Water retention capacity (reduction of available soil moisture) of soils	EEA, JRC, WHO, 2008
3	Landslides	Indicator established by the Commission of the European Communities (Commission of the European Community , 2006)
4	Soil organic carbon content	Indicator established by the Commission of the European Communities (Commission of the European Community , 2006)
5	Loss of soil organic matter	JRC & ies, 2010
6	Soil biodiversity	Indicator established by the Commission of the European Communities (Commission of the European Community , 2006)
7	Soil Contamination (heavy metals, nitrates, phosphates, al saturation)	Indicator established by the Commission of the European Communities (Commission of the European Community , 2006)
8	Soil salinization - Sodification	Indicator established by the Commission of the European Communities (Commission of the European Community , 2006)
9	Desertification	EEA, JRC, WHO, 2008

4.3.1 Soil erosion (by wind and/or rain water)

The processes of soil erosion involve detachment of material by two processes, raindrop impact and flow traction; and transported either by saltation through the air or by overland water flow. Runoff is the most important direct driver of severe soil erosion by water and therefore processes that influence runoff play an important role in any analysis of soil erosion intensity (JRC, 2012). The natural rate of soil erosion can be accelerated by human activity. Changes in the variables of climate (e.g. fading of wind speed, increase of mean precipitation) are highly connected with the wind and rain water erosion. The long dry periods along with regular strong seasonal winds are the main causes for wind erosion, while the force of raindrops, surface and subsurface runoff and river flooding are the main causes for rain water erosion (WMO, 2005). The impacts of these phenomena on soils are more obvious in lands with sparse vegetation cover, erodible soils of semi-arid zone with excess slope greater than 12% (Kosmas, 1999).

Situation in Cyprus: The soil erosion in Cyprus is associated with the long periods of drought, poor vegetation, the heavy rain, the geology and the topography of the island. Erosive effects due to water rain are more frequent in the island (Figure 4-9), especially in plain areas. The geology of the area in combination with the sparse vegetation and the increased frequency of heavy rainfall events are the main causes for the observed erosion in the plain areas of Cyprus.

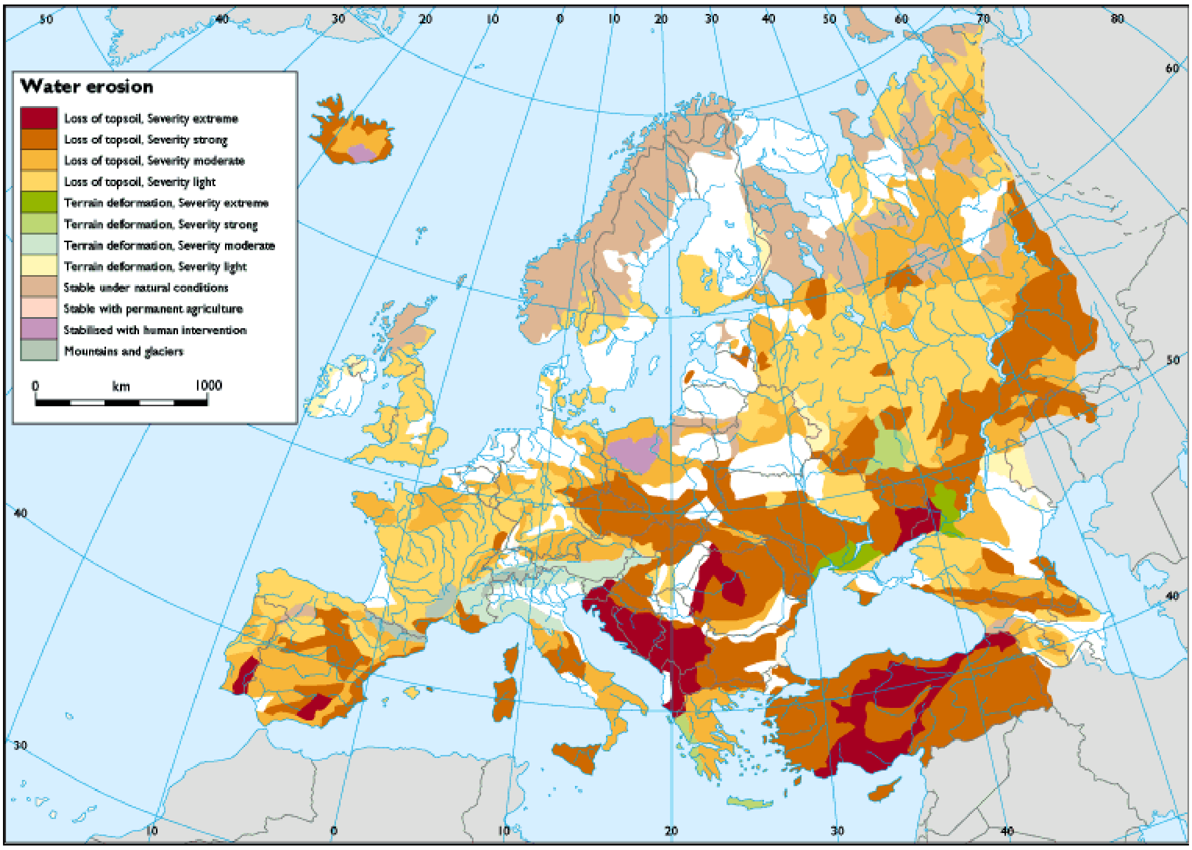


Figure 4-9: Water erosion of soils in Europe according to the GLASOD approach (Van Lynden, 1994)

Source: Soil Erosion Risk in Europe (Grimm et al., 2002)

4.3.2 Water retention capacity (reduction of available soil moisture) of soils

Soil moisture, defined as the amount of water present in the soil, enables soil to be a water repository for the biodiversity of an area. The soil moisture characteristics are the field capacity, the permanent wilting point (PWP) and the available water content. The amount of water actually available for plants (water retention capacity) is the amount of water stored in the soil at field capacity minus the water that will remain in the soil at the permanent wilting point (FAO, 1985). The value of field capacity, which defines the values of water retention capacity, varies from 7% in sandy soils to 40% in clay soils (Voudouris, 2007).

Soil moisture combined with the topography of the area and its soil properties, such as the soil texture, soil structure, porosity, consistence, bulk density, aeration and temperature, determine the rate at which water is lost from the soil (Danoff-Burg J. A., 2002). In addition, soil moisture prevents flooding events and water retention capacity is responsible for the growth of plants (EEA, JRC, WHO, 2008), while both water retention capacity and soil moisture are responsible for the maintenance of the ratio of surface run-off over infiltration. In general, maintaining or even enhancing the water retention capacity of soils can therefore play a positive role in mitigating the impacts of more extreme rainfall intensity and more frequent and severe droughts (EEA, JRC, WHO, 2008).

Situation in Cyprus: The soil composition, which is one of the most important factors for the water retention capacity of soils, varies across regions in Cyprus (see also Table 4-1). The drainage conditions are excellent in the valley and coastal areas, the Chrysochou valley, the narrow valleys of GIalias, Pediaeos, Akaki and Peristerona, Troodos Igneous Massif and the areas of Episkopy-Akrotiri-Garyllis-Yermasoyia. In addition, the drainage conditions are satisfactory in Kokkinochoria and the area of Pissouri-Paralimni while less favourable in the area of Paphos (MANRE).

In order to extract safe conclusions regarding the impact of climate changes on water retention capacity of soils, the following are considered necessary:

- Correlation with climatic conditions and clear distinction of the effect from human activities
- Determination of the water retention capacity of soils in Cyprus
- Data records of long-term series

4.3.3 Landslides

A landslide is the gravitational movement of a mass of rock, earth or debris down a slope (JRC, 2012). The basic parameter evaluated for the determination of the possibility of a soil slippage is the slope stability. A landslide is induced when the shear stress on the slope material exceeds the material's shear strength (JRC, 2012). The causes of landslides include all the factors which influence the terrain and the geo-environment, among which is climate.

The following table (Table 4-5) presents the interrelations between the climate change factors and the associated potential impacts on soil structure, for the case of Cyprus.

Table 4-5 : Potential slope stability responses to specific climate change factors in Cyprus

Climate change	Condition/process affected	Slope stability response
Increase in rainfall intensity	Infiltration more likely to exceed subsurface drainage rates. Rapid build-up of perched water tables.	Landslide triggering by reduction in effective normal stress leading to reduction in shear strength. Increase in cleft water pressures.
	Increased throughflow.	Increase in seepage and drag forces, particle detachment and piping. Piping removes underlying structural support. Enhances drainage unless blockage occurs.
Increased variability in precipitation and temperature	More frequent wetting and drying cycles.	Increase fissuring, widening of joint systems. Reduction in cohesion and rock mass joint friction.
Increased temperature	Reduction in antecedent water conditions through evapotranspiration.	Lower antecedent water status-more rain required to trigger slides.
	Rapid snow melt-runoff and infiltration.	Build-up of porewater pressure and strength reduction.
	Increased sea level.	Enhanced basal erosion on coasts, increase in groundwater levels on coastal slopes.

Source: Deciphering the effect of climate change on landslide activity: A review (Crozier, 2009)

__Situation in Cyprus:__ The soil composition and the excessive slope in certain areas of the Cyprus' mountains create localized phenomena of soil slippage, especially near Paphos. The increase of frequency of heavy rain and the increase of flood events may provoke soil slippage events in these areas.

According to the records kept by the meteorological station of Nicosia (Pasiardes, 2009), an increase of 37-49% has been observed in the intensity and quantity of precipitation for the period 1970-2007 in comparison with the period 1930-1970 for a duration of precipitation between 5 minutes and 6 hours, fact that could increase the risk of soil slippage.

In order to extract safe conclusions regarding the impact of climate changes on landslides, the following are considered necessary:

- Correlation with climatic conditions and clear distinction of the effect from human activities
- Risk mapping of landslides in Cyprus
- GIS Landslide hazard mapping of Cyprus
- Data records of long-term series

4.3.4 Soil organic carbon content

Soil organic carbon is a dynamic part of carbon cycle. It is one of the most important factors for the physical structure and chemical conditions of soil, the soil's water holding capacity and the soil's ability to form complexes with metal ions and supply nutrients (Milne, 2009). Soil organic carbon (*SOC*) is produced during the process of synthesis of food by organisms (EEA, JRC, WHO, 2008).

Changes in climatic variables, such as the increase of temperature, can affect soil organic carbon. Some of the impacts of low organic carbon levels include the reduction in soil fertility, land degradation and depletion of biodiversity. In addition, the organic soils which act as carbon sinks will become a CO_2 and methane source due to the temperature rise, increasing greenhouse gases and subsequently climate change.

Situation in Cyprus: In Cyprus, the greatest carbon pool is soil, with an estimated amount of SOC around 3.884 thousand tons (DoF, 2006). It must be noted that the soil organic carbon content in soil material is in general low (Figure 4-13) and sequestrated in the surface organic layer (Figure 4-11 and Figure 4-12). Nevertheless, this percentage of SOC is typical for areas around the Mediterranean Sea (Figure 4-10). However, there is no data available for the response of low level SOC to climate change for Cyprus.

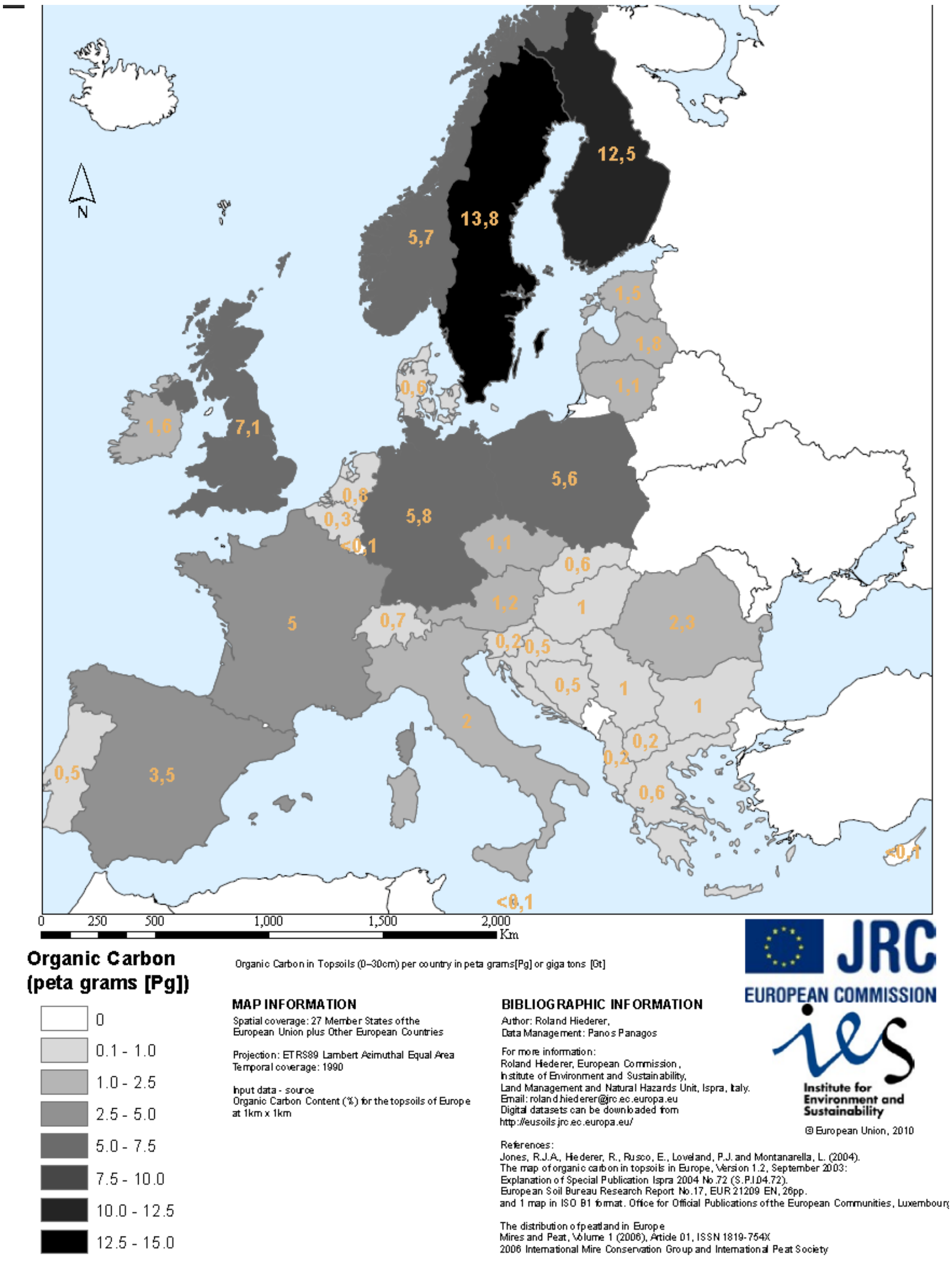


Figure 4-10: Organic carbon per country in peta grams (Pg)

Source: JRC, 2012

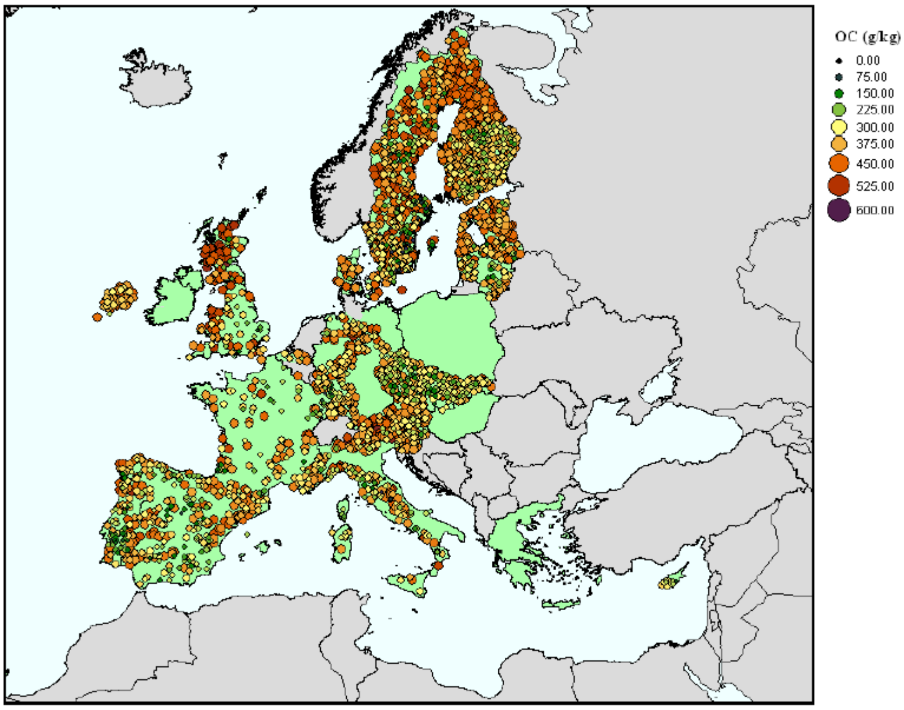


Figure 4-11: Spatial distribution of Organic Carbon Content in Organic Layer

Source: Evaluation of BioSoil Demonstration Project

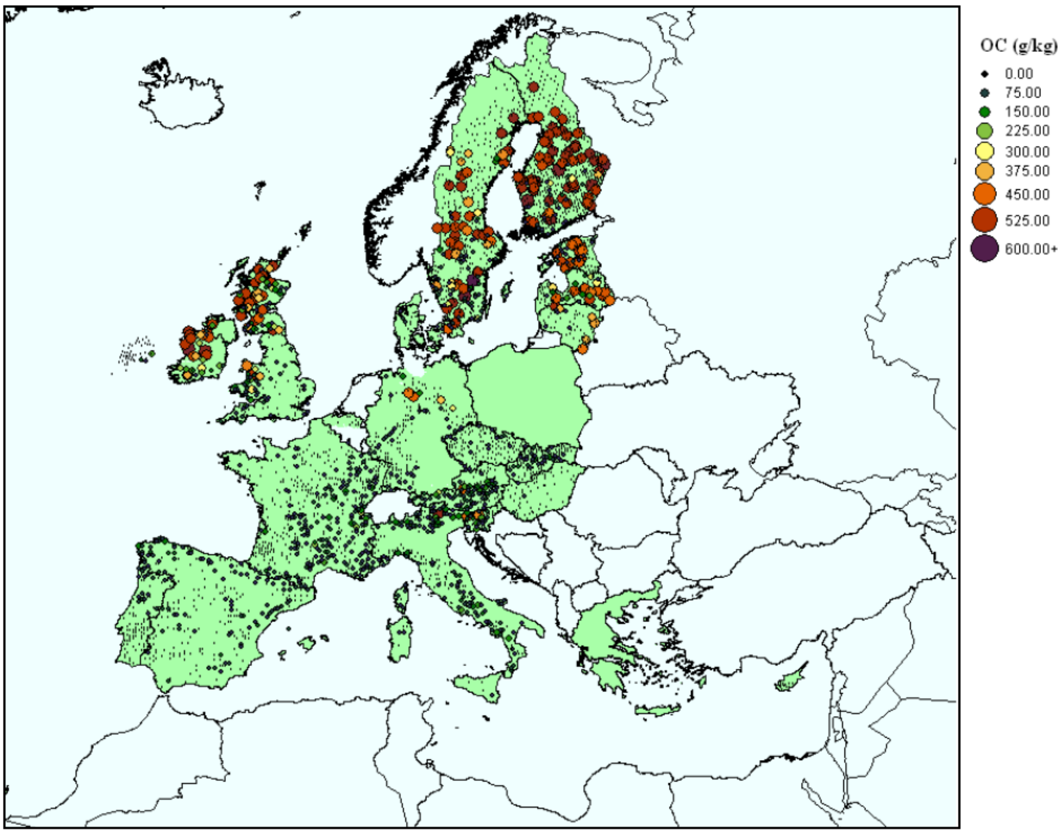


Figure 4-12: Spatial distribution of Organic Carbon Content in Soil Material

Source: Evaluation of BioSoil Demonstration Project

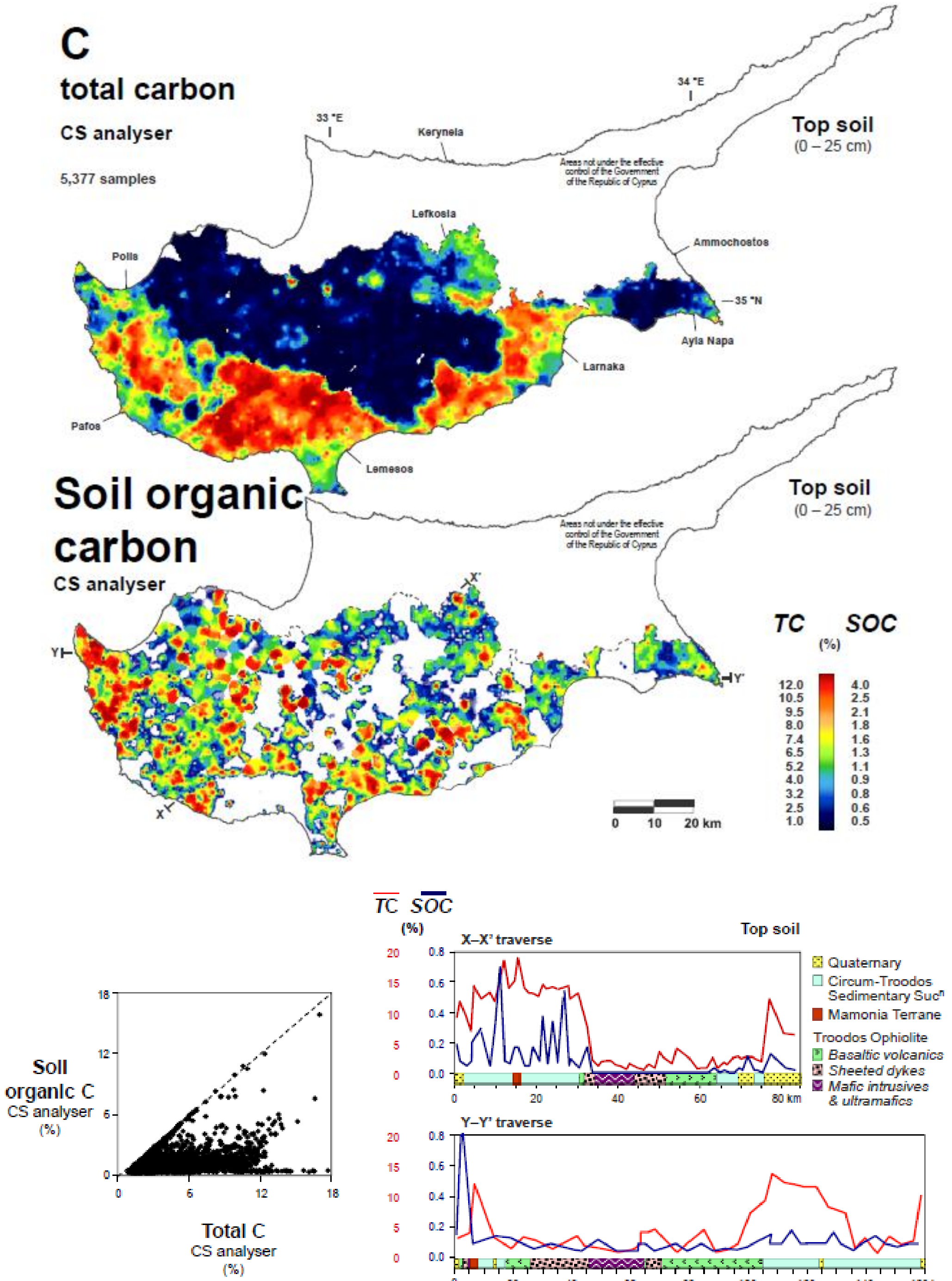


Figure 4-13: Map of total carbon and soil organic carbon

Source: Geochemical Atlas of Cyprus

In order to extract safe conclusions regarding the impact of climate changes on soil organic carbon, the following are considered necessary:

- Data availability from a long monitoring period
- Correlation with climatic conditions and clear distinction of the effect from human activities

4.3.5 Loss of soil organic matter

Soil organic matter (*SOM*), as a major component of global carbon cycle (Schlesinger, 1997), can act both as a sink and a source of carbon in response to climate, land use changes and rising atmospheric levels of CO_2 (Jobbagy & Jackson, 2000; Kirschbaum, 2000). The parameters which influence the indicators of SOM are climate (Alvarez & Lavado, 1998; Ganuza & Almendros, 2003), topography (Burke, 1999; Raghubanshi, 1992), vegetation (Finzi et al., 1998), parent material (Spain, 1990), chronosequence (Schlesinger, 1990) and management (Yang & Wander, 1999). The most important though seems to be temperature and precipitation (Dai & Huang, 2005; Jenny, 1980; Sims & Nielsen, 1986; Homman et al., 1995; Alvarez & Lavado, 1998).

Situation in Cyprus: The mean value of organic matter into the cultivated soils is less than 1% (Hadjiparaskevas). According to the Cypriot Ministry of Agriculture (MANRE), the organic matter content in surface soil in the valley and coastal areas is 1,5%, the narrow valleys of Gialias and Pediaeos 1,5-2,0%, the Morphou alluvial plain 1-2% and the south eastern Mesaoria (Kokkinochoria) less than 1%. The organic matter accumulates in the top 10cm of soil reaching 3-4% in areas of the Troodos Igneous Massif with permanent vegetation on surface, whereas in areas with no permanent vegetation the organic matter content of the surface soil is much lower. The areas of Episkopi-Akrotiri-Garyllis-Yermasoyia have SOM around 1-2%, the areas of Pissouri-Paralimni 1,0-1,5%, Paphos 1,5-2%, the area near Moni-Pareklishia 1% and the surface soil of hilly areas 1,5-2%. Nevertheless, there is no scientific information available for the loss of organic matter due to climate change for Cyprus.

In order to extract safe conclusions regarding the impact of climate changes on soil organic matter, the following are considered necessary:

- Data availability from a long monitoring period
- Correlation with climatic conditions and clear distinction of the effect from human activities
- Determination of soil organic matter values for Cyprus

4.3.6 Soil biodiversity

The species and services of soil biodiversity are directly and indirectly affected by climate change. However, the alteration of soil biodiversity patterns due to global climate change is currently beyond scientific knowledge[1] (JRC & ies, 2010). Some of the main prevailing theories are the following:

Climate change (i.e. temperature rise, decreased precipitation and changes in CO_2) affects soil directly -with the alterations on soil temperature and soil moisture, and indirectly through the changes in vegetation communities, productivity and rate of the organic matter decomposition (EEA, JRC, WHO, 2008). These physical parameters are responsible for some of the main properties of soil biodiversity, but the response of the microflora to the abovementioned changes has not yet been thoroughly examined. According to the "European Atlas of Soil Biodiversity" (JRC & ies, 2010) and the "Impacts of Europe's changing climate, An indicator-based assessment" (EEA, JRC, WHO, 2008), there are clear links between above-ground and below-ground species and diversity (Binkley & Christian, 1998; Gonzalez & Seastedt, 2001; Hooper, et al., 2000). If the above-ground ecoregions are migrating towards the poles and higher altitudes, then it is safe to assume that the below-ground ecoregions will follow, and this clearly has the possibility of leading to some biodiversity losses due to the inability of some biota to adjust in the new environment[2]. On the contrary, according to (Panikov, 1999), the microflora is adapted to survive large changes in both temperature of soil and water content, which are of greater magnitude than the predicted increases in mean temperature or fluctuations of rainfall. Therefore the direct effects are not expected to be very significant (Vallejo et al., 2005).

Another parameter of climate change affecting soil biodiversity is the changes in the interrelations of carbon cycle. Soil biota regulates the decomposition process in substrates, affecting carbon level in soils. According to the "Impacts of Europe's changing climate, An indicator-based assessment" (EEA, JRC, WHO, 2008), the loss of key invertebrates in a low-diversity ecosystem can contribute to significant changes in carbon cycle (Ayres, et al., 2008; Barrett et al., 2008; Poage et al., 2008). On the contrary, according to to (Vallejo, Fierros, & de la Rosa) and the results obtained by (Moscatelli, et al., 2001) in Mediterranean soils: the microbial activity exposed to an atmosphere enriched in CO_2 leads to greater decomposition activity and therefore to a decrease in the organic carbon content of soil. Nevertheless, the effects appear to be short term as there are always taxa prepared to take over the function of others negatively affected by the change especially in a rich and complex trophic web (Setälä & Huhta, 1990; Scheu & Wolters, 1991).

[1] Only some experimental results from extreme environments are available, which demonstrate that an increase in mean temperature usually leads to an increase in bacteria, fungi and nematode numbers but an overall reduction in biodiversity (JRC; ies, 2010).

[2] Nevertheless, the observed displacement in above-ground species and diversity is lower than expected based on calculations of existing data, and this is the reason why this is interpreted as an inability of biota to quick adaptation. More specifically, with all other things being equal, an increase in altitude of 100 m normally equates to a 0.5°C decrease in temperature. This means that the warming that has occurred over the last few decades should have led to a shift in altitudinal ecozones of about 8 to 10 m per decade (JRC & ies, 2010).

Situation in Cyprus: Cyprus has a semi-arid environment and there is extensive sunshine for almost 8 months/year. As a result, the soil moisture in Cyprus is low compared with other climatic types (Figure 4-14) and soil biodiversity is expected to be poor, as only the most resilient species survive in dry conditions (Figure 4-15). Further investigation is required to this respect, as there is no data available for the response of limited soil biodiversity to climate change not only for Cyprus but worldwide too.

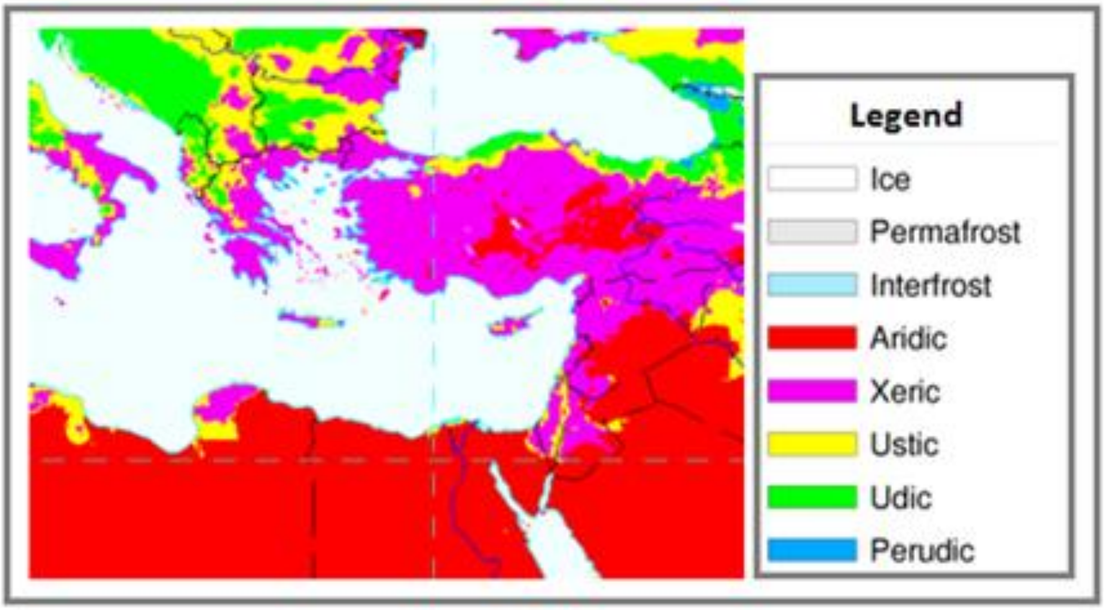
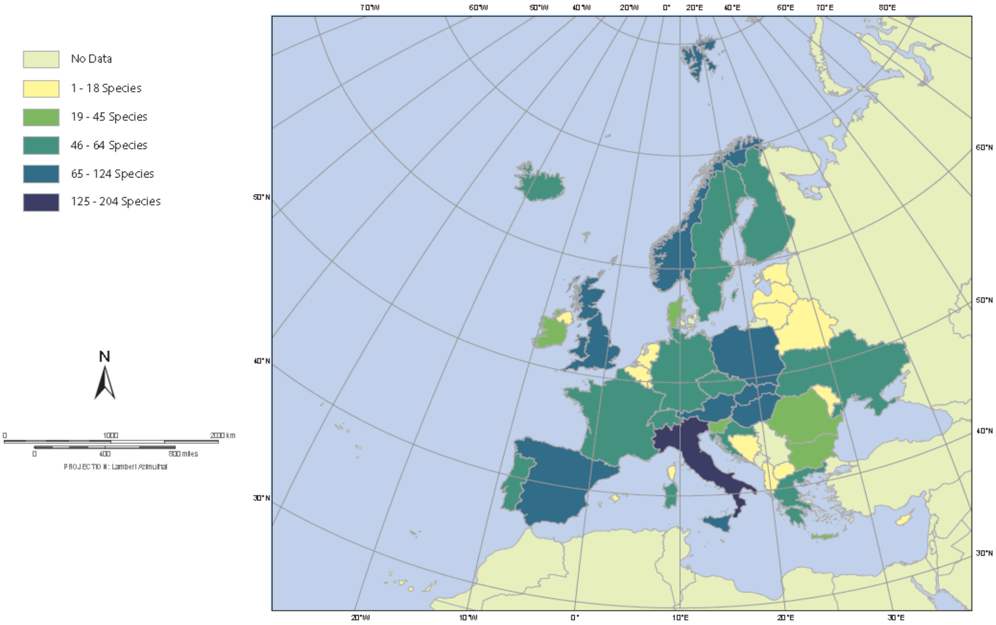


Figure 4-14: Map of soil moisture regimes

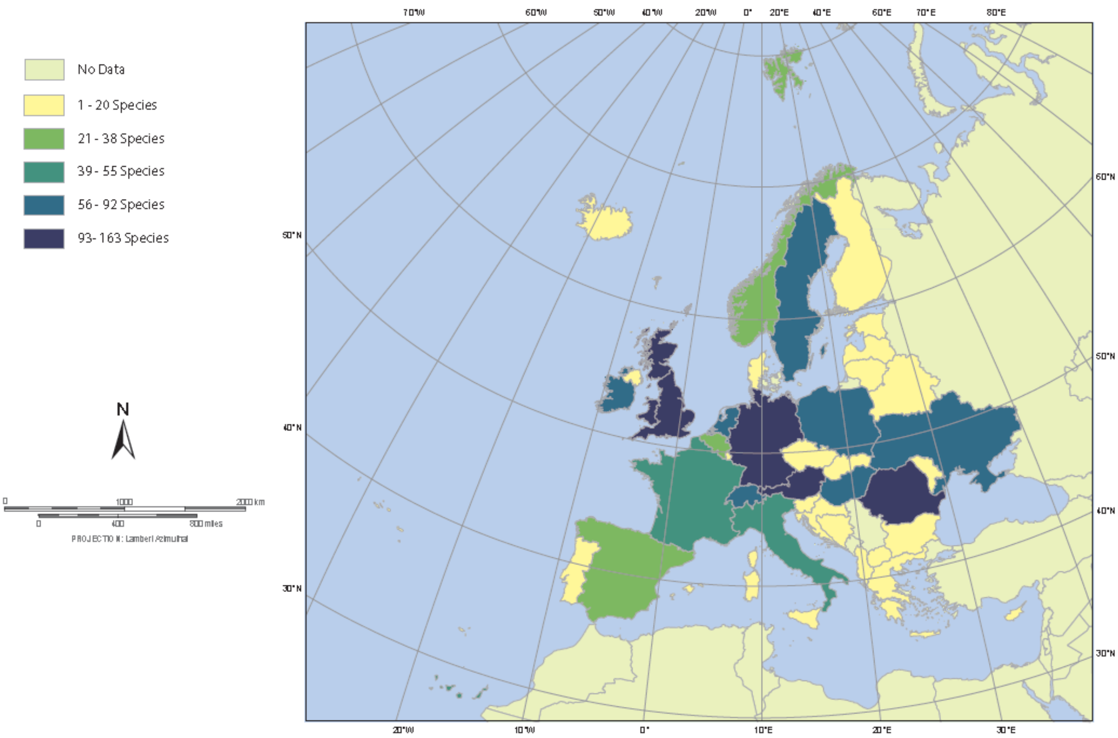
Source: Natural Resources Conservation Service, United States Department of Agriculture, 1999

Distribution Map: Tardigrades

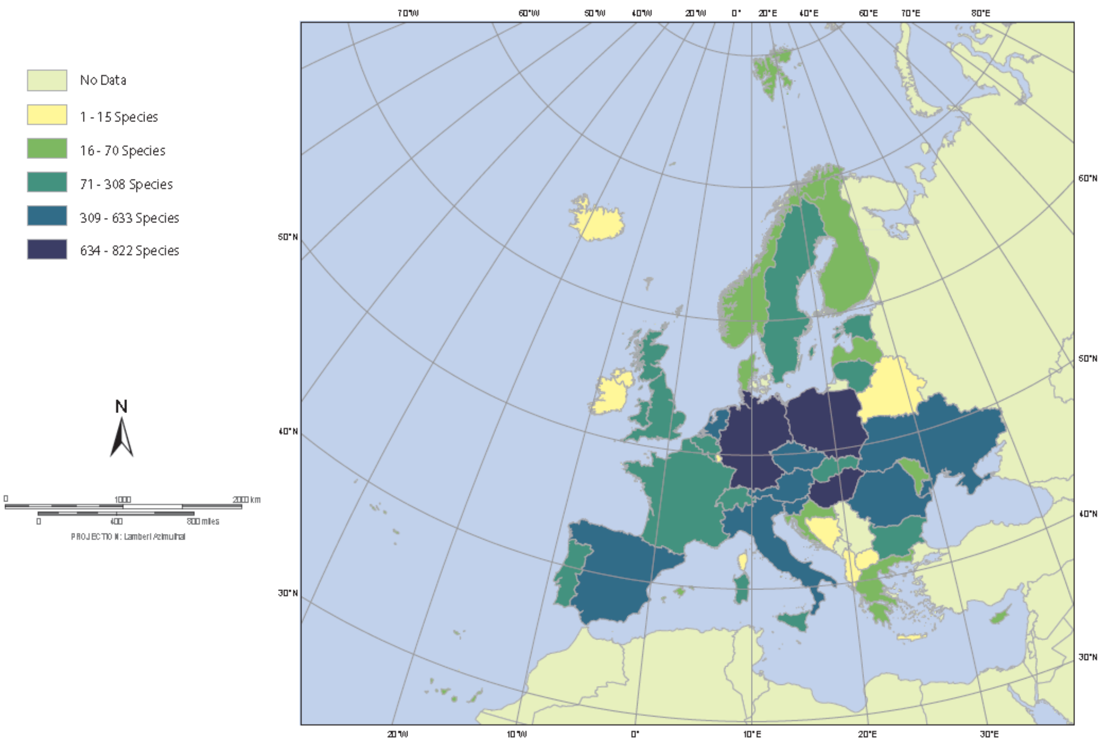
the Support for Research Infrastructures work programme with Thematic Priority Biodiversity.



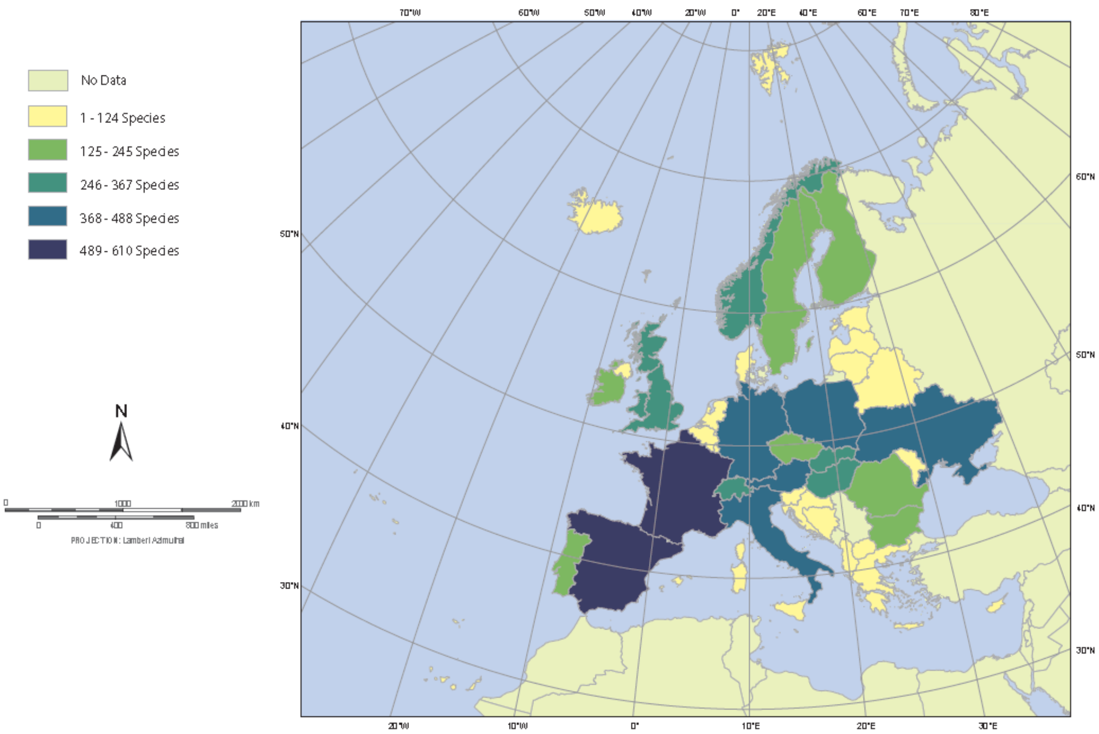
Distribution Map: Rotifers



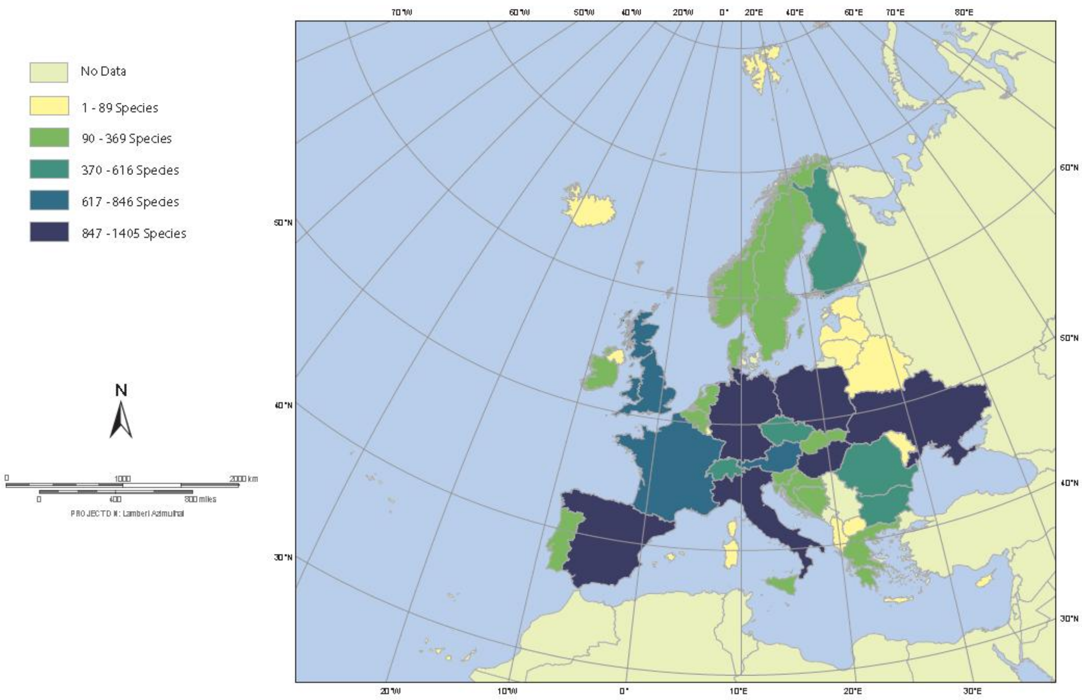
Distribution Map: Nematodes



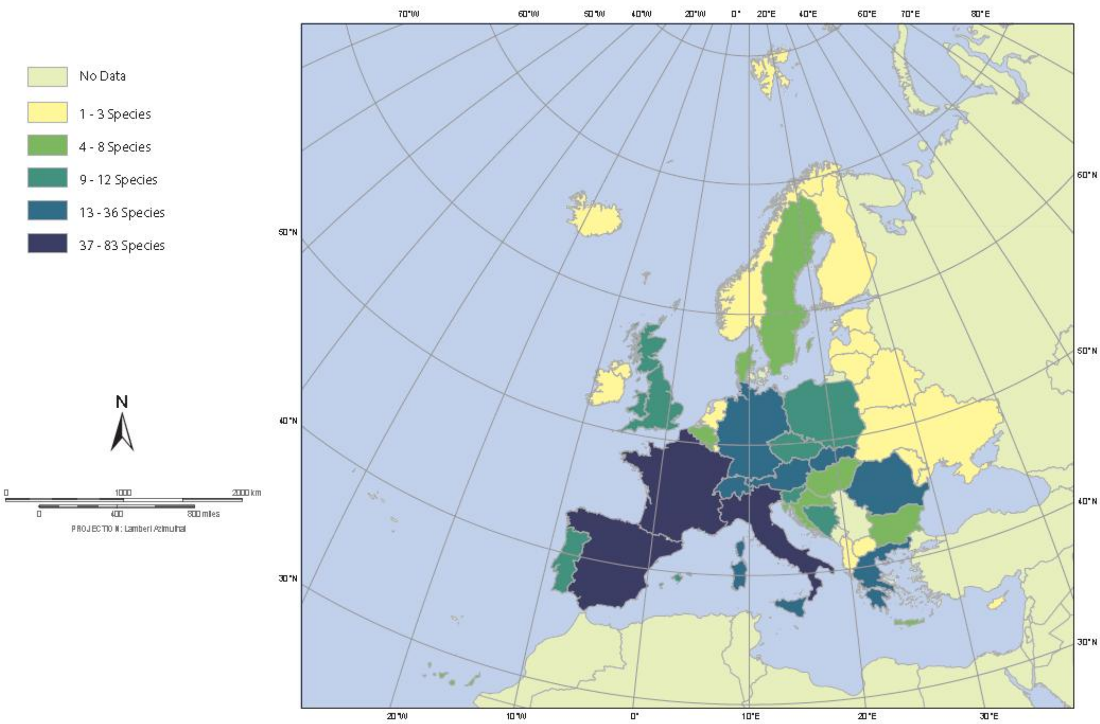
Distribution Map: Collembola



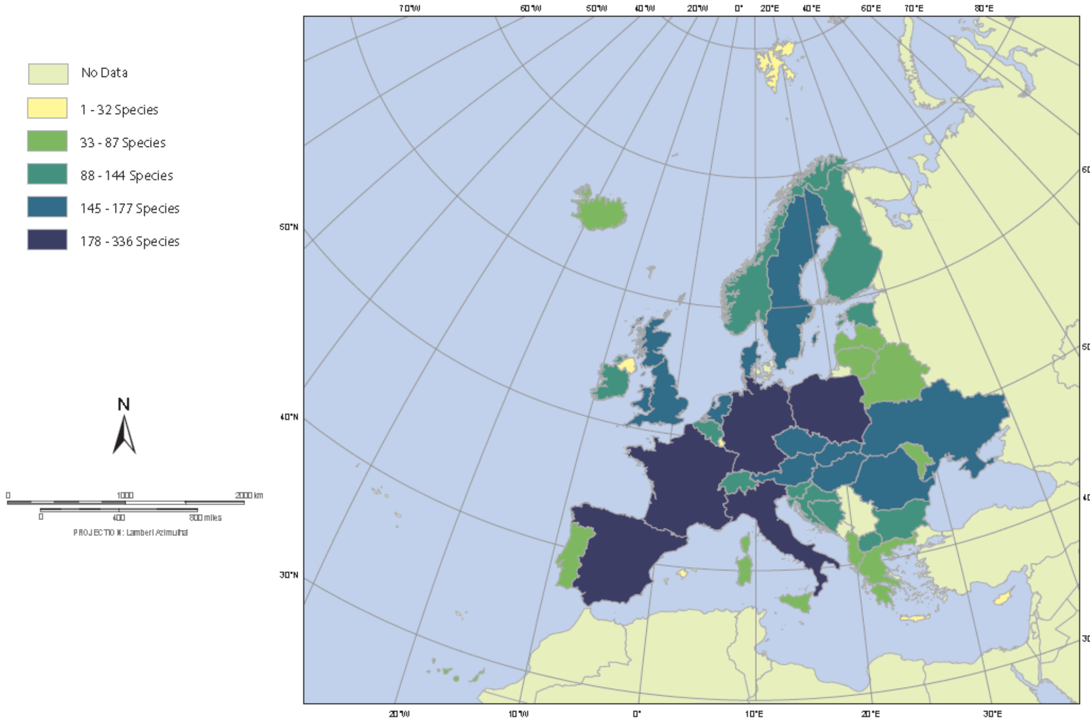
Distribution Map: Acari



Distribution Map: Diplura



Distribution Map: Annelids



Distribution Map: Myriapods

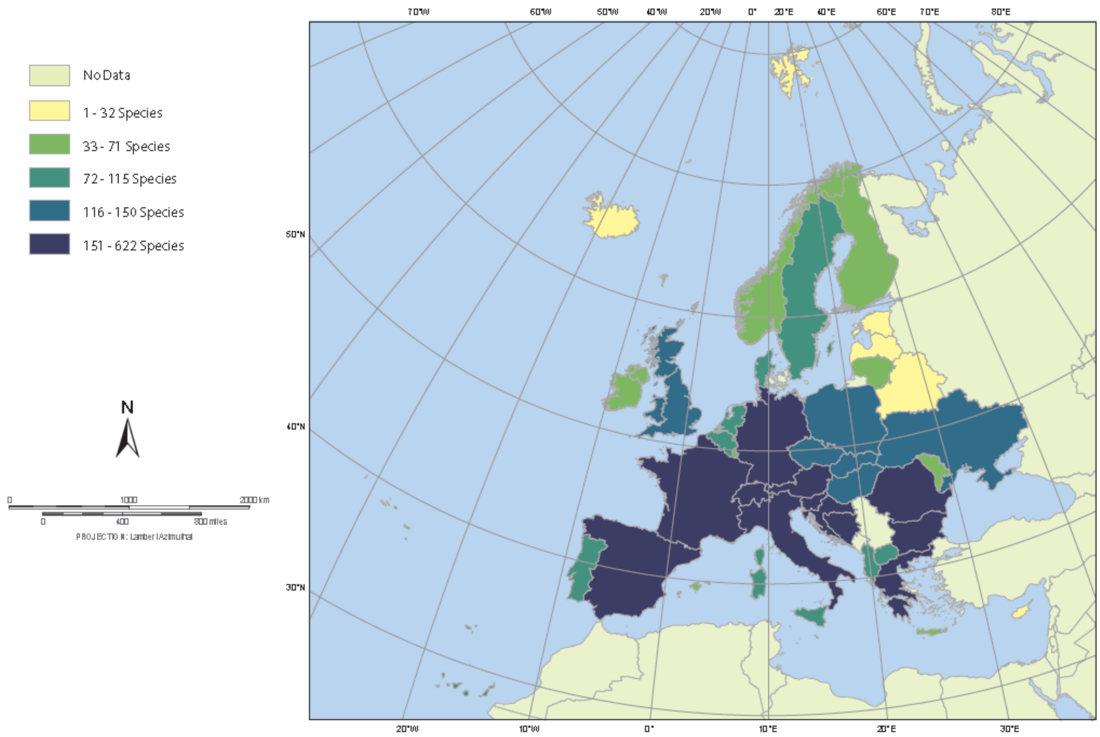


Figure 4-15: Distribution maps of soil faunal groups of Europe

Source: European Atlas of soil biodiversity (JRC & ies, 2010).

In order to extract safe conclusions regarding the impact of climate changes on soil biodiversity, the following are considered necessary:

- Data availability from a long monitoring period about the response of soil biota to climate change
- Mapping of soil biota for Cyprus
- Correlation of soil biodiversity with climatic conditions and clear distinction of the effect from human activities

4.3.7 Soil Contamination (heavy metals, nitrates, phosphates, al saturation)

Some processes of chemical degradation of soils are related to climate change and contribute to desertification. Soil contamination is the occurrence of pollutants above a certain level affecting soil functions, and it can also be considered as the presence of man-made chemicals or other alteration in the natural soil environment (JRC, 2012). This type of contamination -always depending on the degree of industrialization and intensity of chemical usage- typically arises from the rupture of underground storage tanks, the application of pesticides, the percolation of contaminated surface water to subsurface strata, the leaching of wastes from landfills or the direct discharge of industrial wastes to the soil (JRC, 2012). Some of the most common types of soil contamination are analyzed next.

Chemical pollution (heavy metals)

The term “heavy metals” is the most widely recognized and used term for the large group of elements with an atomic density greater than 6 g/m^3 (Alloway, 1990). In the event of heavy metal accumulation in soil, i.e. in excess toward other soil properties, there appear signs of phytoxicity or plants themselves, eventually adapted to such an environment, become toxic to animals and man (Proceedings of the NATO Advanced Research Workshop on Soil Chemical Pollution, 2007).

The factors controlling the total and bioavailable concentrations of heavy metals in soils are of great importance with regard to both human toxicology and agricultural productivity. Apart from the natural occurrence of heavy metals in soils –rarely at toxic levels, other factors such as mining, manufacturing, or the use of synthetic products can result in heavy metal contamination of urban and agricultural soils (USDA NRCS, 2000).

Situation in Cyprus: Chemical pollution in Cyprus may only be located in industrial areas, without posing a serious threat for more distant areas (I.A.CO. Ltd, 2007). However, it must be noted that Industrial activity in Cyprus is limited.

Critical loads for acidification

Acid rain and some fertilizers are responsible for the acidification of soils with low calcium carbonate levels. Continued acid deposition (highly related with climate change due to the increased atmospheric CO_2 concentrations and the acid rain) leaches aluminum (Liu et al., 2009) and magnesium from clay soils lowering the essential for survival of some plants and animals level of pH.

Calcium carbonate soil-buffering capacity is related to soil origin. Soils weathered from rocks high in calcium carbonate have high calcium carbonate buffer capacity.

Situation in Cyprus: Serious incidents of acid rain in Cyprus have not been recorded (I.A.CO Ltd, 2007) since Cyprus is not an industrialized country. Furthermore, soil buffering capacity to acidification in Cyprus is high, due to the high levels of calcium carbonate content of soils (Table 4-8).

Critical loads for nutrients (nitrogen, phosphate)

Nutrients such as nitrogen and phosphorus are critical for controlling ecosystem carbon balance (Schils, et al., 2008). The runoffs with nitrogen, phosphorus and biocides from agricultural practices are responsible for phenomena such as nitrogen or phosphate saturation. Excessive nitrogen and phosphate content in soils cause plant susceptibility to different stresses, altered plant competition in areas where nitrophytic communities tend to replace those adapted to low-nitrogen environments (Bobbink et al., 1998) and soil eutrophication and acidification (Ochoa-Hueso & Manrique, 2010; Bobbink et al., 1998; Cornelissen et al., 2007; Horswill et al., 2008; Nilsson et al., 2006; Stevens et al., 2009).
Availability of nitrogen in many European ecosystems is now significantly enhanced due to atmospheric nitrogen deposition (Schils, et al., 2008). Areas exposed to critical loads of nutrients, such as nitrogen and/or phosphorous, are more common where there is extensive use of fertilizers, uncontrolled landfills or direct discharge of industrial wastes (JRC, 2012). Nitrogen deposition has been estimated to account for approximately 10% of all carbon captured in trees and soil in European forest systems due to the positive effect of tree growth (De Vries et al., 2006; Schils et al., 2008). Unfortunately, the effect of Nitrogen deposition, and nutrient availability in general, on soil organic matter turnover remains largely overlooked by existing models. Assumptions that increased nitrogen availability will reduce organic matter decomposition rates (Fog, 1988; Carreiro et al., 2000; Neff et al., 2002; Hagedorn et al., 2003; Waldrop et al., 2004; Knorr et al., 2005; Schils, et al., 2008) coexist with the contrary hypothesis (Kirschbaum, 1994; Schils, et al., 2008). This implies that greatest effects of nitrogen on carbon storage may be expected in carbon-rich and nutrient-poor systems due to both an increase in production and a decrease in the decay rate of an enlarged recalcitrant organic matter pool. The effects are likely to be considerably smaller in agriculturally managed systems, where nitrogen inputs are higher and where regular soil tillage stimulates soil organic matter turnover (Schils et al., 2008). Some indirect effects of climate drivers on nutrient availability are shown in the following table (Table 4-6).

Table 4-6: Indirect effects of climate drivers on nutrient availability

Indirect effects of climate drivers	Effects on nutrient availability
Experimental warming	Changes in nitrogen availability increase the risk of soil carbon loss.
Drought	Drought has been shown to reduce uptake of phosphorus and other nutrients by trees in the Mediterranean system thus increasing Phosphorus limitation of growth (Sardans & Penuelas, 2007; Sarrdans et al, 2008).
Extreme weather events	Extreme weather events may also be responsible for oscillations in annual net primary production observed (Haddad et al., 2002).
Patterns across rainfall gradients	Patterns across rainfall gradients indicate that concentrations of extractable/exchangeable nutrients generally decrease with precipitation with a widening of Carbon:nutrient ratios (e.g. Austin & Vitousek, 1998). This suggests an asynchrony of carbon and nutrient dynamics driven by different sensitivity of photosynthesis and decomposition to temperature and water availability but also the effect of rainfall and temperature on other abiotic and biotic processes specific to individual elements.

Source: Review of existing information on the interrelations between soil and climate change (Schils et al., 2008).

Situation in Cyprus: In Cyprus, critical loads of nutrients may be located in areas with husbandry waste, irrigated agriculture and uncontrolled landfills, without posing a serious threat for the more distant areas (I.A.CO Ltd, 2007).

4.3.8 Soil Salinization – Sodification

Salinization is the excessive increase of water-soluble salts (Na^+, K^+, Ca^{2+}, Mg^{2+} - Cl^-, SO_4^{2-}, CO_3^{2-}, HCO_3^-) in soil (Varallyay, 2006), which are more soluble than gypsum (Vallejo et al., 2005). Natural soil salinization or primary soil salinization is formed under long-term influence of various natural processes[1], while man-made soil salinization or secondary salinization is the result of salt accumulation in the soil profile caused by extra water input from human activities such as irrigation[2] (Yu et al., 2010; Szabolcs, 1989).

Sodification is the excessive accumulation of sodium (Na^+) in solid (crystallized Na_2CO_3 and/or $NaCCO_3$ salts on the soil surface or on the surface of soil's structural elements; exchangeable ions in the soil absorption complex) and liquid phase (ions in the highly alkaline soil solution) (Varallyay, 2006).

[1] When the water balance of soil does not produce water surpluses, water logging is caused and the salts tend to accumulate on the top soil, osmotically affecting water absorption by the plant producing toxicity (Vallejo et al., 2005)

[2] Irrigation of soils with a high salt content can deteriorate the phenomenon if there is not appropriate drainage, because salts are brought to the surface by the capillary action and the increased growth of the irrigated crop (Vallejo et al., 2005)

Soil salinization is mainly an arid zone problem leading to land desertification. It reduces soil quality, limits the growing of crops, constrains agricultural productivity and, in severe cases, leads to the abandonment of agricultural soils (Martínez-Sánchez et al., 2010). Such conditions can be exacerbated by increased temperature and reduced precipitation. Furthermore, climate change will increase flood incidence and salinity along coastal regions through the influence of sea-level rise (UNEP, 2001).

Situation in Cyprus: The accumulations of salts in soils of Cyprus are the results of the soil composition, the use of treated irrigation water with high percentage of salts and the use of saline water for irrigation from boreholes. The temperature rise, with the more frequent drought periods, in combination with the increased water demand can deteriorate the water quality and quantity and as a result the soil quality and productivity.

4.3.9 Desertification

Desertification is an irreversible process (Mainguet, 1994) caused by several interdependent parameters and triggered by the combination of the natural predisposition of the environment with human pressure and climate change (Adamo & Crews-Meyer, 2006; UNCED, 1992; Santini, et al., 2009). Numerous soil factors cause desertification including intensive and continuous erosion, reduction of nutrients, acidification, reduction of water holding capacity, salinization and lack of water (I.A.CO Ltd, 2007), reduction in the organic content of the soil due to a lower permanent biomass and decreased production of litter, fragile soil structure due to decreased organic matter, lower permeability, water intake and storage, soil surface crusting by raindrop, lower biological activity from micro-, meso- and macroflora and fauna, and particularly symbionts and reduced soil productivity (Le Houerou, 1995). In addition, climate change may exacerbate desertification through alteration of spatial and temporal patterns in temperature, rainfall, solar radiation and winds (WMO, 2005).

Desertification is an increasing threat for the soil resources of southern Europe and the Mediterranean. More specifically, the phenomenon in arid semiarid and arid sub-humid areas is responsible for the loss of production yield, reduction of water availability, reduction of hydropower potential and land degradation, affecting relevant dimensions such as the ecology, income and quality of life (I.A.CO Ltd, 2007).

Situation in Cyprus: The factors contributing to desertification in Cyprus -as identified in the study conducted by I.A.CO. (I.A.CO Ltd, 2007)- are climate, topography, geology, soil composition, hydrology and human factors such as urban development and reduction of rural population.

Desertification is a serious problem for Cyprus, since the 57% of the island is characterized as “Critical”, the 42,3% as “Fragile” and only the 0.7% as “Potential” to desertification (I.A.CO Ltd, 2007). Climate change and in specific reduction of precipitation and temperature rise, can deteriorate the phenomenon.

4.4 Vulnerability assessment

In this section, the vulnerability of soil resources to climate change impacts is assessed in terms of their sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which soils are affected by climate changes, exposure is the degree to which soils are exposed to climate changes and their impacts while the adaptive capacity is defined by the ability of soil resources to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The indicators used for the assessment of sensitivity, exposure and adaptive capacity of Cyprus soils to climate change impacts are summarized in Table 4-7.

Table 4-7: Indicators used for the vulnerability assessment of climate change impacts on the soil resources of Cyprus

Vulnerability Variable	Selected indicators
Soil erosion (by wind and/or rain water)	
Sensitivity	For wind erosion – Soil composition – Wind velocity – Long dry periods associated with regular strong seasonal winds – Sparse vegetation
	For water rain erosion – Soil composition – Sparse vegetation cover – Intensity of rain – Surface and subsurface runoff* – River flooding
Exposure	– Areas of sparse vegetation – Areas of soil surface roughness – Areas with erodible soils – Areas of limited soil fertility – Land uses (maps) – Areas where slopes have slope greater than 12%
Adaptive capacity	– Terracing – Natura 2000 – Measures for the protection of the coastal areas from erosion – National Forest Strategy – Rural Development Program 2007-2013 (Measures 2.1 and 2.3.6.)
Landslides	

Sensitivity	– Slope stability* – Soil composition – Increase in rainfall intensity
Exposure	– Areas of recorded soil slippage events
Adaptive capacity	– Technical structures – Terracing (with grants from the E.U.) – Research project entitled 'Study of landslides in areas of Paphos District'
Soil contamination	
Sensitivity	– Acidification of soils – Nitrogen and phosphorus content of soils
Exposure	– Surface percentage of areas of calcic soils (for the acidification of soils) – Areas of uncontrolled landfills – Areas with wastes from husbandry – Areas with irrigated agriculture
Adaptive capacity	– Nitrate Directive – Good Agricultural Practices – Enforcement of the European legislation – Water Pollution Law
Soil salinization-sodification	
Sensitivity	– Soil composition – Treated irrigation water with high percentage of salts – Saline water from aquifer boreholes for irrigation – Frequency of drought periods
Exposure	– Areas of salinized soils – Crop areas using inferior quality water
Adaptive capacity	– Enforcement of Water Framework Directive – Salt Infiltration capacity of rain
Desertification	
Sensitivity	– Overexploitation of water and soil resources – Growing water demand – Economic growth and development of the urban and coastal areas – Aging of the rural population – Abandonment of the traditional agricultural activities

	– Reduction of rainfall – Topography – Poor on desertification and erodible soils
Exposure	– Areas of soil sealing and soil compaction – Areas of increased groundwater use and demand – Abandoned areas – Areas of excessive slopes – Area (surface percentage) of prone to desertification and erodible soils
Adaptive capacity	– Surface percentage of vegetation cover – Measures for combating desertification applied on the agricultural sector, the forest sector, the animal husbandry sector, the water resources sector, the coastal areas, the societal and economic sector – Measures for the elimination of $SO_{x,}$ NO_x, VOCs and NH_4 emissions.

* No date available for this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability of soil resources in Cyprus is assessed for the following impact categories presented in Section 4.3:

1. Soil erosion (by wing and/or rain water)
2. Landslides
3. Contamination (heavy metals, nitrates, phosphates, al saturation)
4. Soil salinization-sodification
5. Desertification

The vulnerability of the impacts “*Water retention capacity (reduction of available soil moisture) of soils*”, “*Loss of soil organic matter*”, “*Soil organic carbon content*” and “Soil *biodiversity*” also presented in Section 4.3, was not assessed for the case of Cyprus due to lack of sufficient research data.

The vulnerability of soils varies substantially as it is related to the different rate and magnitude of climate change in different parts of Cyprus due to the variability of the air pollution levels, altitude, temperature and rainfall variations, meteorological conditions (e.g. wind, moisture), local geomorphology and soil characteristics.

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability. In case additional data are provided by the competent authorities of Cyprus, the vulnerability of the sector could be re-assessed.

4.4.1 Soil Erosion (by wind and/or rain water)

4.4.1.1 Assessment of sensitivity and exposure

Sensitivity

Wind erosion is increased by wind speed and reduced by soil surface roughness. Erosion by wind (movement of very small particles on the surface) occurs when wind speed exceeds 4,5m/s. In Cyprus, a statistical analysis on winds indicates that at coastal areas the mean annual wind velocity at 10m ranges between 4 and 6 m/s, and reduced further inland (Pasiardes, 1995). Particularly high velocities in certain high points of Mesaoria plain are due to strengthening of westerly winds by the funneling effect between the Troodos and the Kyrenia mountains (I.A.CO Ltd, 2007). As a result wind erosion in Cyprus is a rare and very slow procedure.

The soil erosion due to rain water in Cyprus is intensive in plains, mostly due to the soil composition and the sparse vegetation cover (Figure 4-16 and Figure 4-17,). As a result, a change in the intensity and pattern of precipitation can affect these areas significantly.

Considering the above, the sensitivity of soil erosion (especially rain water erosion) in Cyprus can be characterized **moderate to high.**

Exposure

Wind erosion is not very common in Cyprus, but can be severe in areas with low vegetation cover (I.A.CO Ltd, 2007), erodible or pulverized soils and hilly areas with slope greater than 12% (Kosmas, 1999). In specific, soils with shallow rock contact (Leptosols, Lithosols, Lithic Xerorthents) -especially those formed on limestone of the semi-arid and arid zones, and soils of dry hilly areas have a reduced resistance to erosion. Such erodible soils are located in the central mass of Troodos range, due to their shallow, rocky with steep slopes features (slope of 18% and 12% cover the 10% and 22% of the island respectively). Nevertheless, the soils of mountain areas in Cyprus are not prone to wind erosion due to the vegetation cover, as someone may see from Figure 4-16and Figure 4-17.

Rain water erosion has damaged the horizon A (topsoil consisting the first 0-25cm of ground) of many areas of the island of Cyprus, such as Aradippou-Koshi (I.A.CO Ltd, 2007). Soil erosion has obvious impacts on reduced soil fertility of the area, especially in areas where soils are shallow (Figure 4-17) or have subsurface of low fertility.

Overall, the large soil surface exposed to soil erosion is mainly lowland (flat areas) (Figure 4-17) and as a result the characterization can be **high**.

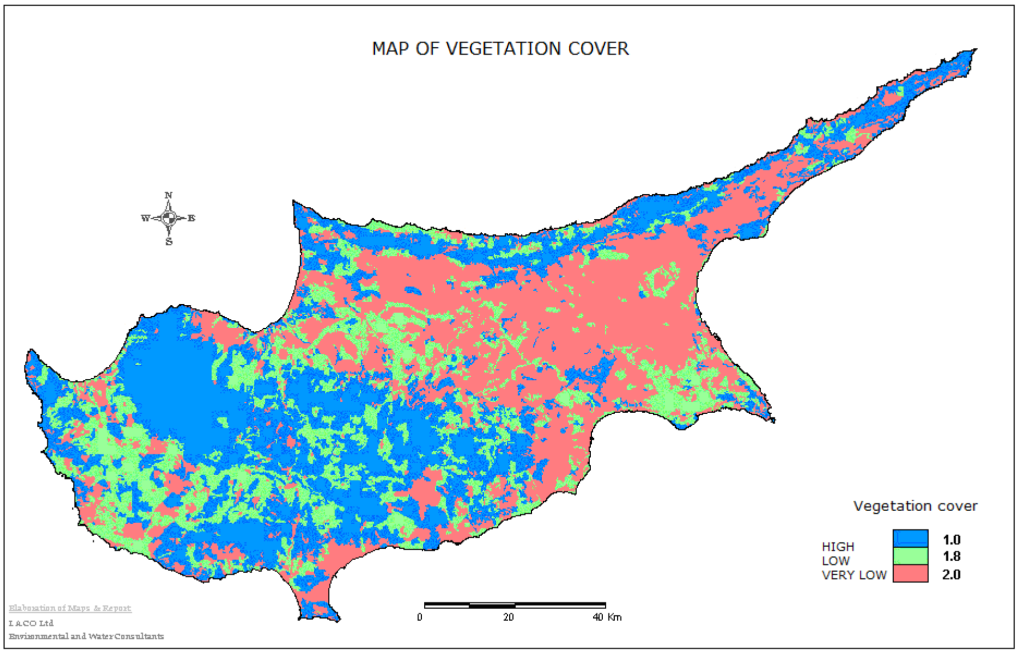


Figure 4-16: Map of vegetation cover

Source: I.A.CO Ltd, 2007

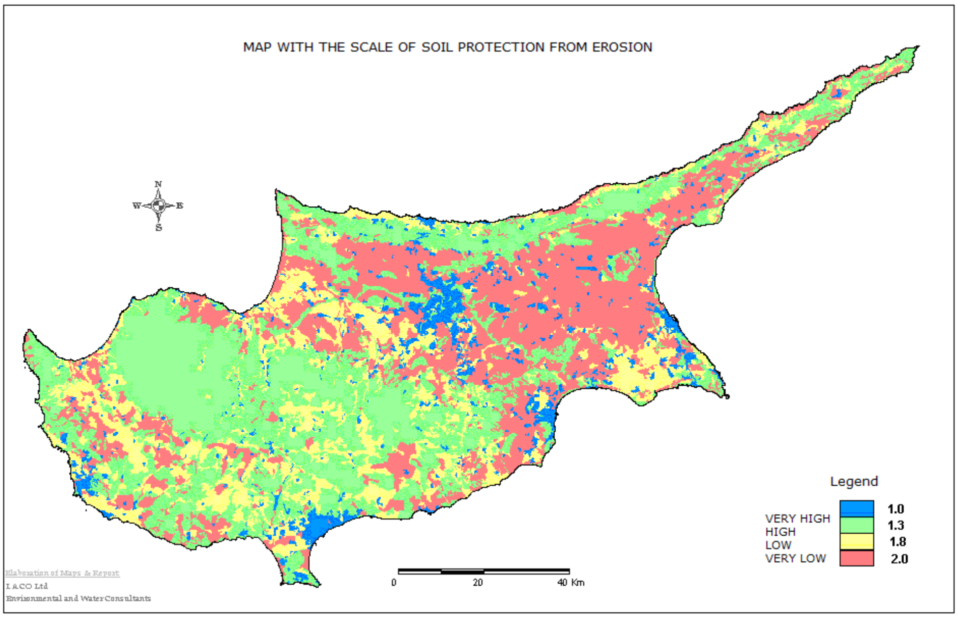


Figure 4-17: Map with the scale of soil protection from erosion

Source: I.A.CO Ltd, 2007

4.4.1.2 Assessment of adaptive capacity

The resilience of soils against wind and rain water erosion is intrinsically not very high due to the great surface cover of the island with erodible soils (Figure 4-17) and the disproportion between dense vegetation cover of mountains and low vegetation cover of plains (the percentage of land covered by forests is 16.7%, crops 47,82% and permanent crops only 3,9%)(Figure 4-18, Figure 4-19).

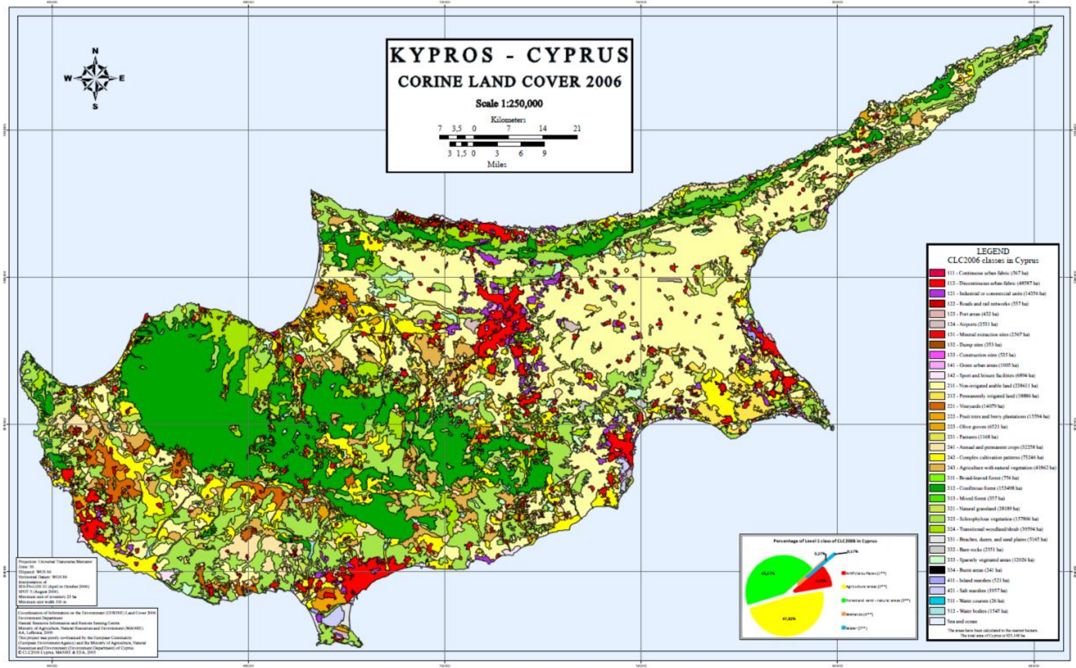


Figure 4-18: Cyprus Corine Land Cover (EEA, 2006)

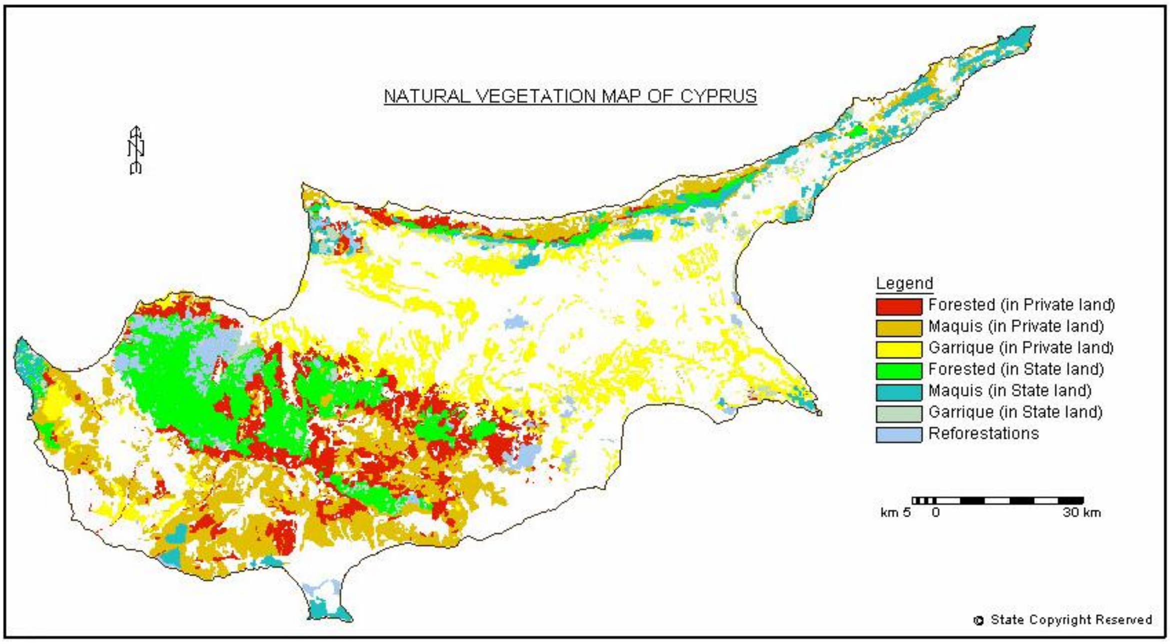


Figure 4-19: Natural vegetation of Cyprus

Source: I.A.CO Ltd, 2007

The measures applied in Cyprus which enhance soil protection from erosion are presented next:

i) The Good Agricultural and Environmental Conditions, which are a group of measures setting minimum requirements for reducing run-off and soil erosion, are listed below:

- Minimum soil cover: There should be a natural / plant vegetation for the cover of land with a slope greater than 10% during the period of rainfalls.
- Minimum land management reflecting site-specific conditions: In a land with a slope greater than 10%, contour plowing must be exercised. Soil cultivating during periods of heavy rain should be avoided, especially in clay and heavy soils.
- Terracing: Terraces / stone walls and natural slopes at the boundaries of the crop holdings should be maintained in a condition to prevent erosion. The construction of terraces is also financially supported by the Rural Development Programme.

These requirements are obligatory for those farmers receiving direct payments from the Rural Development Programme.

ii) Provision of subsidies to farmers through the Rural Development Programme (RDP) for increasing vegetation cover and reducing run-off, especially in mountain areas. The related measures of the RDP are:

- Measure 2.1: "Compensatory Allowances in Less Favoured Areas". Eligible activities under this measure are the exploitation of agricultural or fallow land mainly in mountain areas with permanent, semi-permanent or perennial crops and prevent land abandonment.
- Submeasure 2.3.6: "Agri-environmental commitments in traditional plantations of trees and shrubs, with emphasis on less favored areas ". The scheme aims to reduce pollution of groundwater and soil from the use of chemical fertilizers, to protect biodiversity and preserve traditional landscape, by simultaneously contributing to soil protection from erosion and to retain the population in mountainous areas. The eligible action foreseen under this scheme is the mechanical destruction of weeds instead of the use of chemical means.
- Submeasure 2.4.3: "Afforestation of non agricultural land". The exploitation of non agricultural land with tree planting is expected to reduce environmental degradation and to enhance biodiversity.

iii) Farm-level measures protect soil from erosion by reducing run-off from agricultural land, especially when livestock manures have been applied. Nevertheless, farm-level restricted application depends on the private initiative of farmers.

iv) The protection of forests from fires also contributes to the reduction of soil erosion and run-off, as trees have the capacity to retrain water through their deep routes. The Department of Forests has elaborated and continuously upgrades an extensive programme of fire protection measures. However, fire protection measures have not been enforced for private forest-covered lands, which cover 23,12% of the island. Following, such organized activities that take place in Cyprus are presented.

- The National Programme of Forests foresees the expansion of forest cover through afforestation of hali and other abandoned private land and the reforestation of burnt areas.

– The Rural Development Programme provides incentives for the afforestation of agricultural and non-agricultural lands (Submeasures 2.4.1 & 2.4.3).

v) Control grazing is another measure for preventing soil erosion and thus run-off. In Cyprus, the Forests Law prohibits grazing in the forests since 1913, while the Goats Law of 1988 determined the maximum number of animals, especially goats, which is permitted to graze in order to prevent overgrazing and identified the areas where grazing is allowed. However, this Law is not applied in most cases, as there is no sufficient control.

vi) The application of Advanced Irrigation Systems reduce run-off and increase soil moisture, as irrigation is applied in such a way that the soil can better absorb water without losses. A Water Use Improvement Project has been implemented in Cyprus by the Department of Agriculture since 1965.

vii) Measures undertaken for the protection of the coastal areas from erosion are the construction of hard defense structures and beach nourishment (for further information see Section X: Coastal zones).

viii) The preservation of animal and plant species of an area constitutes protection for soil too. The network of the protected areas Natura 2000 in Cyprus is given in Figure 4-20.

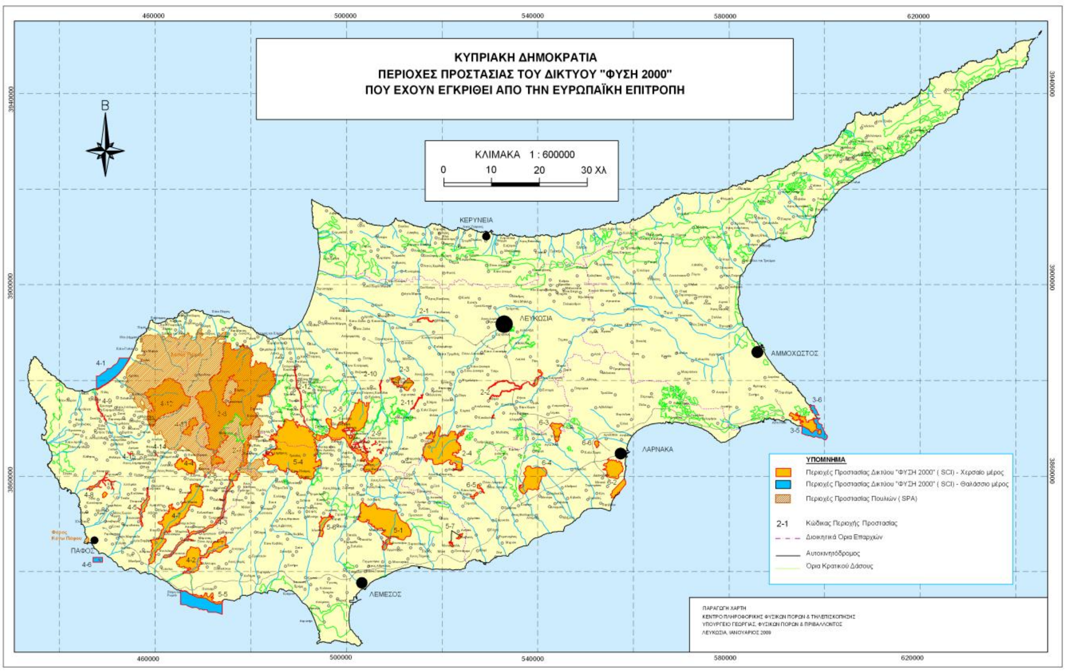


Figure 4-20: “Natura 2000” Network for Cyprus

Source: MANRE

ix) Restoration of natural features such as hedgerows, floodplains and woodlands improve water retention in soils, absorption and run-off, and buffer agricultural land from extreme weather events. Since the majority of adaptation measures regarding this issue require action at the farm level, the government measures to assist adaptation mainly refer to the provision of economic incentives to farmers.

x) Sustainable agricultural practices protect soil from erosion. Raising awareness is essential in order for the farmers to be aware of how and why sustainable agricultural practices are applied. Relative measures foreseen in the Rural Development Programme are:

- Measure 1.1 "Vocational training and information, including dissemination of scientific knowledge and innovative practices for persons engaged in agriculture, food and forestry " . Through the actions of this measure, the opportunity is provided to farmers to be trained on issues such as the integrated and sustainable management of natural resources, the application of production practices compatible with conservation and enhancement of landscape and the environmental protection and proper implementation of agri-environmental measures.
- Measure 1.4 " Use of Farm Advisory Service (FAS) ". The Farm Advisory System (FAS) is a system for advising farmers on land and farm management. Farmers are encouraged to take part with a facility to claim for financial assistance to use the provided service.

Although there is a rich set of indigenous strategies and policy processes, they are not sufficient to reduce negative impacts of climate change. The multiple stressors of soil erosion are difficult to be addressed in semi-arid climate types such as Cyprus. As a result, the adaptive capacity of soils to erosion in Cyprus is characterized as **limited to moderate.**

4.4.2 Landslides

Although data records of long-term series are necessary for the evaluation of the impact of “Landslides” for Cyprus (a series of 30-40 years data set is currently available), an attempt was made to present the current susceptibility of Cyprus to landslides and its probable vulnerability of landslides to climate.

4.4.2.1 Assessment of sensitivity and exposure

Sensitivity

Soil composition, tectonics and topography are factors which increase susceptibility to soil slippage. In addition, climate change increases the likelihood for land displacements.

Cyprus is well-known for its interesting and often complex geology, particularly in the south-west part of the island. In specific, in some parts of the Paphos District, landslides cover a large percentage of the landscape, including many types of landslide in a relatively small area (such as deep-seated rotational landslides, through translational block movement and topples, to shallow mudflows). The reason for the increased susceptibility of this area to landslides is the remains of former sea-floor deposits and massive submarine slides, which tend to be heavily deformed and are rich in the types of clay minerals that are prone to landsliding. This tendency is exacerbated by the steep terrain and the long history of powerful earthquakes in the region (British Geological Survey).

In addition, certain meteorological records in the area indicate increase in the intensity and quantity of precipitation, which could be relevant for more landslides. More specifically, records from the meteorological station of Nicosia show a 37-49% increase in the intensity and quantity of precipitation for the period 1970-2007 in comparison with the period 1930-1970 for a duration of precipitation between 5 minutes and 6 hours (Pasiardes, 2009).

Considering the above, the sensitivity of Cyprus to landslides can be characterised as **moderate,** especially for the mountain areas.

Exposure

Landslides are common in certain areas of Cyprus, but it was not until recently that the Ministry of Agriculture and Natural Resources and Environment undertook a relevant research project entitled 'Study of landslides in areas of Paphos District' for recording the landslide events. The project used aerial photography and QuickBird satellite imagery, supported by field verification and Terrain Classification mapping in order to identify and map 1842 landslides, cataloguing them within a GIS-based landslide inventory. This has shown that landslides cover approximately 24% of the 546km^2 project study area, with the largest (compound) landslides reaching almost 3km width and 4,5 km length, comprising spreads of calcareous cap-rock, block slides and substantial earth flows (Hart et al., 2010). In the following, some of the types of landslides in Cyprus are presented (Research and Development Center – Intecollege Unit of Environmental Studies, 2004) :

1) Relatively large and active slope failures and landslides occur in the western part of the island (Paphos District), where rocks of the Mamonia Complex and the Kannaviou Formation are exposed. Characteristic examples of landslides are observed in the villages of Mamonia, Kannaviou, Statos, Pentalia, Kritou Marottou and Anadiou.
2) In the southern part of the island (Limassol District), landslides relate to the Lower Marls of the Lefkara Formation as well as the Moni Formation (bentonite). Examples can be seen in the areas of the villages of Kilani, Silikou, Doros, Korfi, Triklini as well as Moni and Pentakomo.
3) In the northwest part, landslides can be observed along the roads from Morphou to Skylloura and from Myrtou to Panagra.
4) Rock falls are observed mainly in the mountainous areas of Cyprus and in natural and manmade slopes. Examples of rock falls have been observed in Lemithou, Akrounta, Pelentri, Prodromos and along the road from Nicosia to Kyrenia.

5) In Cyprus, sinkholes are formed in lithological units that contain either gypsum or limestone and they are the products of the dissolution of these two lithologies by water, Sinkholes in gypsum occur all over the island, in particular in the areas of Pissouri, Maroni, Aradippou, Kathikas, Kalavassos, Nisou, Pergamos and between Lefka and Galinoporni. The sinkholes are rather small in size, may have an irregular shape and constitute foundation “traps”. When their roof collapses due to weight of the civil structure on top, sinkholes may cause subsidence problems.
6) The long mining history of Cyprus has resulted in extensive waste dumps in many areas such as Kalavassos in the south, Limni in the worthwest, Mitsero and Mathiatis in central Cyprus and Troulli in the east. Thus, under certain conditions the slopes of these dumps may develop landslide phenomena.

In addition, another study for the evaluation of landslide risk in Europe (Figure 4-21) show that in some places of Cyprus (in specific areas near Paphos and the mountains of Troodos), the landslide risk varies from moderate to high with respect to their landscape susceptibility (Figure 4-21).

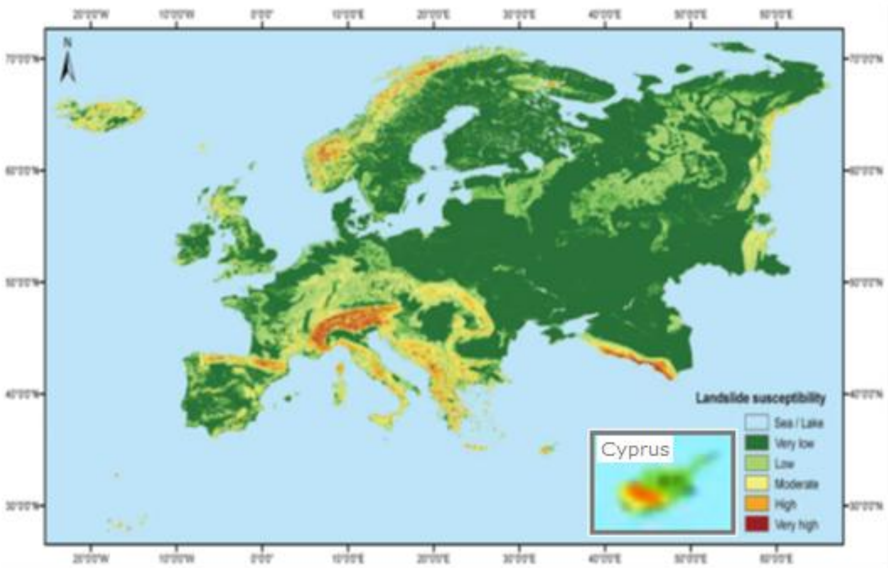


Figure 4-21: Classified landslide susceptibility map of Europe

Source: Van Den Eeckhaut et al., 2010

Consequently the exposure to landslides can be characterized as **limited to moderate**.

4.4.2.2 Assessment of adaptive capacity

The localized landslides have been encountered with some technical structures and terracing with grants from the European Union in order to prevent the soil loss. In addition, a two-year research program of the Geological Survey Department of Cyprus in collaboration with the British Geological Survey and more recently as part of Scott Wilson's was carried out in order to map landslides of Paphos, including mapping and analysis of digital satellite images (British Geological Survey). Last, one of the most drastic measures taken was the relocation of of certain mountainous settlements to safer places.

A) In addition, a number of measures undertaken either separately or in conjunction with one another to face the problem of slope failures and landslides. Such measures include:

- The decrease of the dip of the slope
- The unloading of the land-slit mass
- The construction of berms and terraces
- The controlled pumping of ground water to maintain a stable water table
- The construction of drainage system and retaining walls

B) Depending on the characteristics of each case or rock fall, different measures can be taken to resolve the problem. The most frequently used method for facing the problem is the installation of anchors and rock bolts.

C) Remedial measures are often very difficult and include filling up the sinkhole with grout.

Consequently the adaptive capacity of landslides to climate changes can be characterized as **moderate,** due to the fact that landslide is a physical phenomenon not easily controlled as it depends mainly on geology and soil composition.

4.4.3 Soil Contamination (heavy metals, nitrates, phosphates, al saturation)

4.4.3.1 Assessment of sensitivity and exposure

Sensitivity

The risk of soil acidification in Cyprus is **limited** because most of the soils have well-developed carbonate accumulations (calcic soils) (I.A.CO Ltd, 2007) as shown in the following table (Table 4-8). The calcic soils, due to their high concentrations of calcium carbonate (including limestone and dolomite), are more resistant to acid rain [1].

Table 4-8: The calcium carbonate content of soils in Cyprus

Areas of Cyprus	Calcium carbonate content of soils
Valley and coastal areas	45–55%

[1] The calcium carbonate (chemically) neutralizes acids, and this is why "liming" is used as an ecological restoration method to adjust the pH of lakes affected by acid rain (Ghosh, 2002).

Areas of Cyprus	Calcium carbonate content of soils
Chrysochou valley	30-40%,
Narrow valleys of Gialias, Pediaeos	10-20%,
Morphou alluvial plain	50%,
South eastern Mesaoria (Kokkinochoria)	0-3%,
Troodos igneous massif	do not contain free calcium carbonate
Areas of Episkopi-Akrotiri-Garyllis-Yermasoyia range	from 10-30% to 60-70%,
The areas of Pissouri-Paralimni	50-60%,
Soils on the “Nicosia” geological formation	40-60%,
Paphos	10-30%,
Area near Kalavasos	60-70%,
Area near Moni-Pareklishia	free from calcium carbonate
Hilly areas except those on the “Mamonia” geological formation	50-70%.

Source: MANRE

Exposure

Soil contamination in Cyprus is mainly located in areas with extensive use of fertilizers, urbanization, wastes from husbandry, or uncontrolled landfills. Areas with nitrogen pollution in groundwater bodies such as the areas Kokkinohoria, Kiti-Pervolia, Akrotiri, Paphos, Poli Chrysohous, and Orounta which were identified as Vulnerable Nitrate Zones according to the Directive 91/676/EC (MANRE, 2008), are also possibly exposed to soil pollution too.

Furthermore, the European Environment Agency recently released the report “Exposure of ecosystems to acidification, eutrophication and ozone (CSI 005)” which was published in 2012. According to the report, the percentage of natural ecosystem area at risk of acidification and eutrophication reveals the extent of the problems for certain countries. The European Environment Agency classified Cyprus, among the 32 EEA member countries and EEA cooperating countries in 2000 for current legislation (CLE) in 2010 (EEA, 2012), in the countries with the lowest percentage of ecosystem area at risk of acidification and eutrophication as shown in Table 4-9, Figure 4-22 and Figure 4-23.

Table 4-9: Percentage of natural ecosystem area at risk of acidification (left) and of eutrophication for the 32 EEA member countries and EEA cooperating countries in 2000 and for two emission scenarios: current legislation (CLE) in 2010 and 2020, maximum feasible reduction scenario [1]

	Eutrophication					Acidification				
	Area (km^2)	2000 (% at risk)	CLE 2010 (% at risk)	CLE 2020 (% at risk)	MFR 2020 (% at risk)	Area (km^2)	2000 (% at risk)	CLE 2010 (% at risk)	CLE 2020 (% at risk)	MFR 2020 (% at risk)
Albania	16 954	100	99	99	43	16 954	0	0	0	0
Austria	40 255	100	94	78	5	35 746	2	1	0	0
Bosnia & Herxegovina	31 892	89	81	77	40	31 892	17	15	10	0
Belgium	6 250	100	99	94	37	6 250	29	21	19	4
Bulgaria	48 330	94	91	80	18	48 330	0	0	0	0
Switzerland	9 625	99	96	91	21	9 805	9	5	3	1
Cyprus	2 461	68	68	68	17	2 461	0	0	0	0
Czech Republic	27 626	100	100	100	99	27 626	28	22	20	5
Germany	102 891	84	67	58	36	102 891	58	32	24	5
Denmark	3 584	100	100	100	99	3 584	50	42	37	2
Estonia	24 728	67	57	47	5	24 728	0	0	0	0
Spain	187 115	95	93	90	48	187 115	3	0	0	0
Finland	240 403	47	41	36	2	273 634	3	2	2	0
France	180 099	98	95	91	41	177 359	12	8	6	1
United Kingdom	92 244	26	19	17	9	81 815	39	19	15	7
Greece	53 671	98	97	97	60	53 671	3	1	1	0
Croatia	31 698	100	100	99	81	31 698	5	3	3	0
Hungary	20 805	100	100	100	56	20 805	26	8	7	0
Ireland	2 449	88	81	77	73	8 935	23	8	6	2
Iceland	6 122	0	0	0	0	61 22	16	13	11	7
Italy	124 788	69	61	55	14	124 788	0	0	0	0
Liechtenstein	26	100	100	100	92	26	52	32	0	0
Lithuania	19 018	100	100	100	92	19 018	34	32	32	4
Luxembourg	1 015	100	100	99	98	1 015	15	13	13	0
Latvia	35 823	99	99	96	44	35 823	20	14	12	0
The FYR of Macedonia	13 945	100	100	100	53	13 945	12	1	0	0
Netherlands	4 447	94	88	88	76	6 968	76	71	71	60
Norway	137 701	22	14	11	0	179 158	16	11	10	3
Poland	90 330	100	100	99	68	90 330	77	61	50	3
Portugal	31 121	97	83	69	6	31 121	8	3	3	0
Romania	97 964	19	20	15	0	97 964	46	22	12	0
Sweden	150 865	56	47	43	13	443 660	17	10	9	2
Slovenia	10 996	98	92	82	0	10 996	7	0	0	0
Slovakia	20 532	100	100	100	83	20 532	18	9	8	0
Serbia & Montenegro	41 108	97	95	92	34	41 108	18	9	3	0

Source: EEA, 2012

The percentage of sensitive ecosystems at risk of chemical changes with negative effects on ecosystem function and structure caused by acidification has been calculated by the EEA as the share of sensitive ecosystems for which critical loads for acidification are exceeded by deposition of acidifying nitrogen sulphur compounds.

[1] Hettelingh J-P, Posch M, Slootweg J (eds.) (2008) Critical load, dynamic modelling and impact assessment in Europa: CCE Status Report 2008, Netherlands Environmental Assessment Agency.

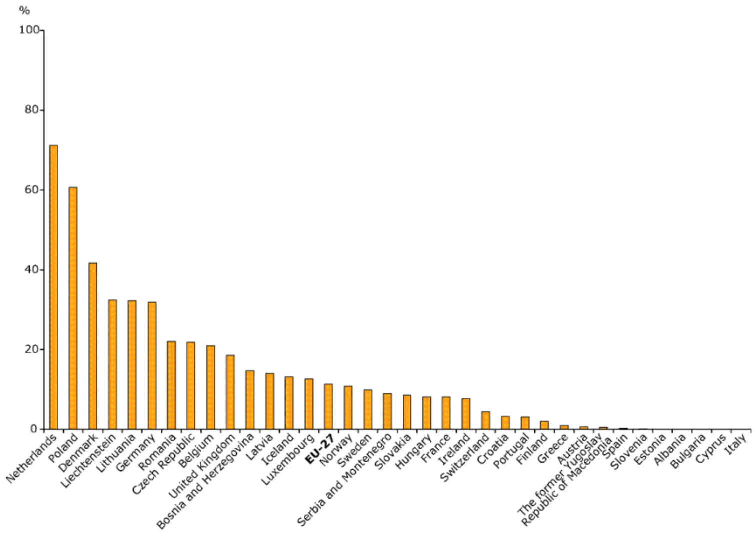


Figure 4-22: Percentage of ecosystem area at risk of acidification for EEA Member Countries and EEA Cooperating Countries in 2010 for a current legislation (CLE) scenario[1]

Source: European Environment Agency, 2012

The percentage of ecosystem at risk of eutrophication and negative changes in nutrient balances is presented in Figure 4-23. This percentage has been calculated by the EEA as the share of sensitive ecosystems for which decomposition of oxidized and reduced nitrogen compounds exceeds the critical loads.

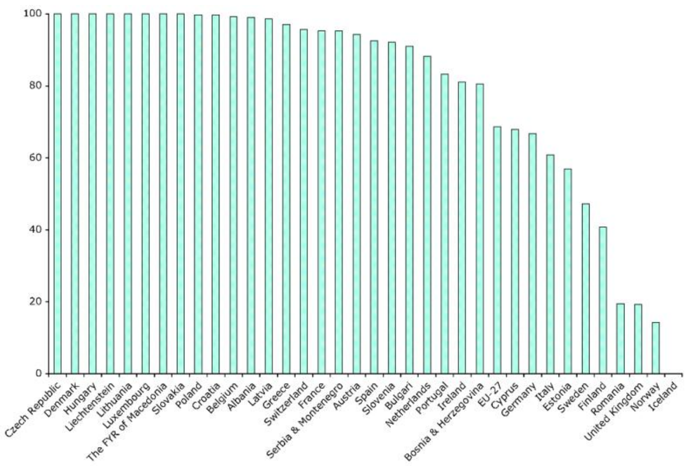


Figure 4-23: Percentage of ecosystem area at risk of eutrophication for EEA Member Countries in 2010 for a current legislation (CLE) scenario[2]

Source: European Environment Agency, 2012

[1] The results were computed using the 2008 Critical Loads database. Deposition data was made available by the LRTAP Convention EMEP Centre for Integrated Assessment Modeling (CIAM) at the International Institute for Applied Systems Analysis (IIASA) in autumn 2007.

[2] The results were computed using the 2008 Critical Loads database. Deposition data was made available by the LRTAP Convention EMEP Centre for Integrated Assessment Modeling (CIAM) at the International Institute for Applied Systems Analysis (IIASA) in autumn 2007.

More specifically for the forest ecosystems of Cyprus, a research survey was carried out calculating the critical loads of acidity and nutrient nitrogen for Cyprus forest ecosystems in order to identify sites where deposition levels have reached a critical state and ecosystems could be at risk. Calculation of critical loads is based on a mass balance approach that takes into account atmospheric deposition, stand structure, bedrock and soil chemistry. Deposition scenarios compiled by the Centre for Integrated Assessment Modelling (CIAM) of the European Monitoring and Evaluation Programme (EMEP) were provided by the ICP Modelling and Mapping programme. A comparison between deposition rates and critical loads allowed to compute the so-called exceedance. For Cyprus at that time only the EMEP yearly deposition dataset of acidifying sulphur and nitrogen pollution (50 by 50 km grid cells, EMEP 2003) was available, allowing for a very rough estimation on exceedances. The comparison between the deposition values in 2000 with the critical loads showed that nowhere are exceedances in Cyprus (Nagel, 2003; LRTAP/IWF, 2011).

The reason is the relatively high acid neutralisation capacity of the mostly calcareous soils in Cyprus resulting in high critical loads. As depositions are actually underestimated, local sources were also taken into account. As a result it was estimated that about 17 % of the natural ecosystems area is stressed by acid depositions near the critical loads. The area is located at the lowlands between Pentadactylos and Troodos mountains. In these areas the main vegetation types are maquis and garique which are characterized by low critical loads. The comparison between the deposition values of nitrogen compounds in 2000 (EMEP 2003) with the critical loads shows exceedances in about 60 % of the Cyprian ecosystems. The critical loads of halophytic vegetation in salt lakes and lagoons near Ammochostos, Lemesos and Morfou are exceeded more than twice, but also at the Pentadactylos mountains the actual depositions are higher than critical loads. Also at the circum Troodos sedimentary succession area exceedance of critical loads is observed. Only critical loads at the Troodos forests are not exceeded at all (Nagel, 2003).

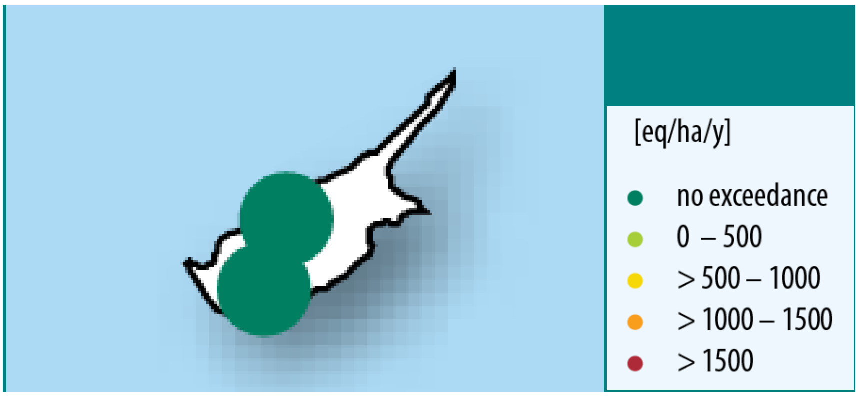


Figure 4-24: Exceedance of critical loads for nutrient nitrogen in 2000

Source: LRTAP/IWF, 2011

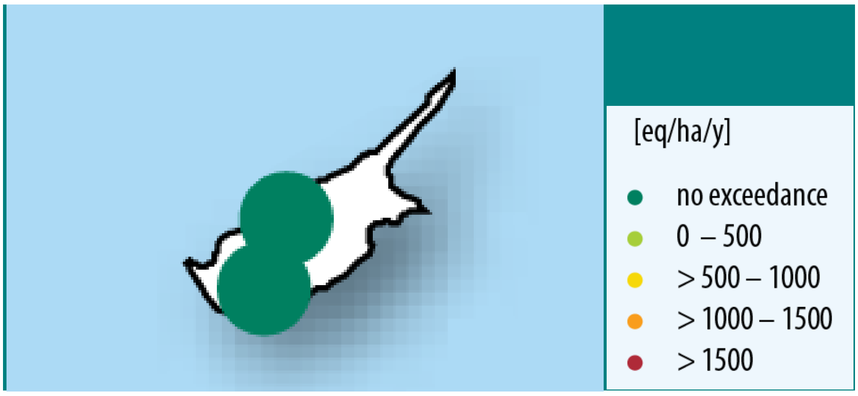


Figure 4-25: Exceedance of critical loads for acidity in 2000

Source: LRTAP/IWF, 2011

Considering the above, the exposure of this factor can be characterized **moderate**.

4.4.3.2 Assessment of adaptive capacity

The Pollution Control Division of the Ministry of Agriculture, Natural Resources and Environment of Cyprus has the responsibility for the protection, control and prevention of pollution of water and soil from the operation of industrial and farming activities as well as any other human activity that may or tends to pollute the waters and the ground. The relevant for the protection of water and ground form pollution legislation "The Control of Water Pollution Laws of 2002 to 2009" include the law 106(I)/2002 and its amendments (160(I)/2005, 76(I)/2006, 22(I)/2007, 11(I)/2008, 53(I)/2008, 68(I)/2009, 78(I)/2009).

Furthermore the Directive 91/676/EEC on the protection of waters against pollution caused by nitrates has been harmonized in the legislation of Cyprus with the Law on Water Pollution Control No. 106(I)/2002. For its implementation, the Department of Agriculture has established a (i) Code of Good Agricultural Practice as well as an (ii) Action Plan to prevent or reduce water pollution from nitrates.

i) Code of Good Agricultural Practice

The Code of Good Agricultural Practice which has been enacted by the Presidential Decree No. 263/2007 aims to reduce nitrate pollution from fertilizer use and livestock waste and the introduction of acceptable practices for the use of recycled water in irrigation and municipal sludge in agriculture that protect public health and the environment. However, the compliance with the guidelines of the code is prescriptive.

For certain types of facilities with significant potential 'polluting' activities implemented additionally "on the Integrated Prevention and Pollution Control Laws of 2003 - 2008" (Law 56 (I) / 2003, Law 15 (I) / 2006 and Law 12 (I) / 2008). These laws aim to prevent emissions to air and discharges to water and land-based weather and take the necessary measures, notably the introduction of Best Available Techniques (BAT) in order to achieve the highest level of environmental protection.

The protection of waters and soil, under the above laws guaranteed are related to the granting discharge authorizations under the Ministry of Agriculture, Natural Resources and Environment. Permissions define environmental terms, depending on the type of each facility, for the rational management of liquid and solid wastes and their disposal in a controlled environment.

The implementation of the abovementioned measures has resulted in a significant reduction of soil contaminating activities in Cyprus. However, the natural remediation of the soils requires several years to take place while there are several techniques which are applied for the decontamination of soils. Consequently, the adaptive capacity to soil contamination in Cyprus is considered to be **moderate**.

4.4.4 Soil Salinization – Sodification

4.4.4.1 Assessment of sensitivity and exposure

Sensitivity

Soil salinization in Cyprus is a combination of natural soil salinization and man-made soil salinization or secondary salinization. In Cyprus almost the soils are characterized as alkaline (Koudounas, 2001; I.A.CO Ltd, 2007), which is a subcategory of the salinized soils[1]. In addition, certain areas are affected by soil salinization due to the use of treated waste water with high salt content and the use of inferior quality water from aquifer boreholes for irrigation in combination with the more frequent consecutive years of droughts and the increased water demand. As a result, the sensitivity of soil salinization for Cyprus can be characterized **moderate to high**.

Exposure

Cyprus has **moderate** exposure to soil salinization and the soils of the affected areas on the eastern part of the island are saline more than 50%, as shown in the following map (Figure 4-26). Certain areas of Larnaca are affected by the use of treated waste water with high salt content, and others (such as Akrotiri, Syrianochori, Livadia–Oroklini, Acheritou–Egkomi and on the west of Larnaca) by the use of inferior quality water (I.A.CO Ltd, 2007).

[1] Salinized soils are classified as: saline (EC >4, ESP <15), saline-alkaline (EC >4, ESP>15) and alkaline/sodic (EC <4, ESP >15) (Majerus, 1996).

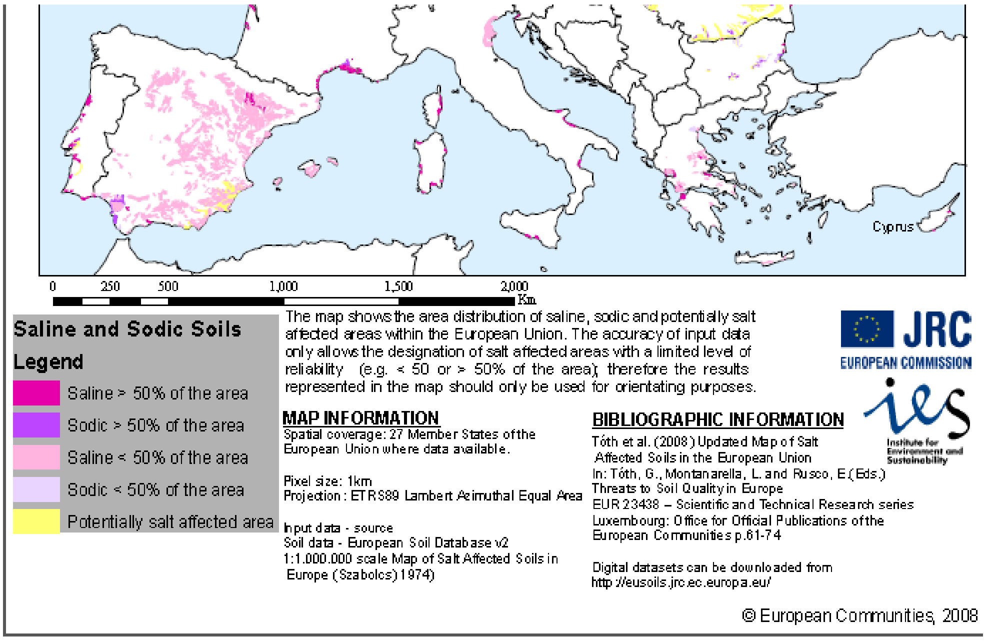


Figure 4-26: Saline and sodic soils in European Union

Source: JRC, 2012

Saline soils in Cyprus are located mainly in the eastern part of the island, mainly due to the irrigation of crops with water from salinized aquifers. As regards to aquifer salinization, the aquifers located at the coasts – i.e. all major aquifers of Cyprus - are exposed to seawater intrusion and especially those located in low-lying areas (e.g. Larnaca). As a result, 12 out of 19 groundwater bodies in Cyprus have been exposed to saline intrusion while the coastal zones of several aquifers in Cyprus have been abandoned due to this phenomenon (Figure 4-27). It must also be noted that a potential sea-level rise would increase the amount of seawater intruded into freshwater aquifers.

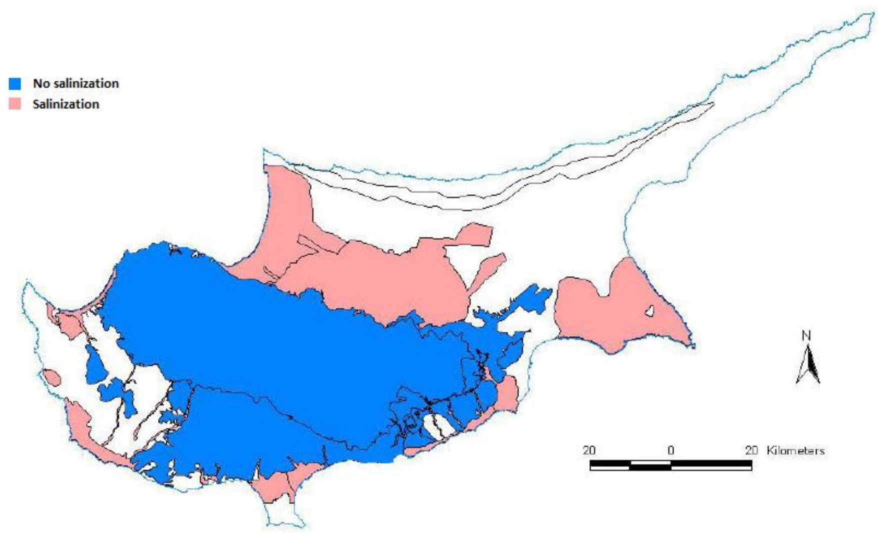


Figure 4-27: Salinization in the groundwater bodies of Cyprus

Source: WDD, 2008

4.4.4.2 Assessment of adaptive capacity

Studies have shown that the accumulations of salt are washed out to the sea with precipitation. Furthermore the law on the control of groundwater abstractions to reduce overexploitation and salinization "Integrated Water Management 79(I)/2010" which has been enforced in Cyprus since 2010, sets strict requirements on the granting of permissions for the drilling of boreholes and the pumping of groundwater. Furthermore, the Law foresees the installation and monitoring of water meters in boreholes, in order for the quantities of water pumped not to exceed the limits set. It is expected that with the new Law a considerable number of violations, that have been made in the past, will be eliminated. What is more, the salinity of the water used for irrigation and recharge is monitored in order to avoid further deterioration of the groundwater bodies. Considering the above, the adaptive capacity of soil resources in Cyprus is **limited to moderate**.

4.4.5 Desertification

4.4.5.1 Assessment of sensitivity and exposure

Sensitivity

Certain physical characteristics of the island such as the typical semi-arid climate of the island, the eroded plains and the poor and erodible soils (Figure 4-28 and Figure 4-31) are responsible for the naturally increased sensitivity of the island towards desertification. The only areas which are less prone to desertification are the mountain areas of Troodos due to the dense vegetation cover (Figure 4-29).

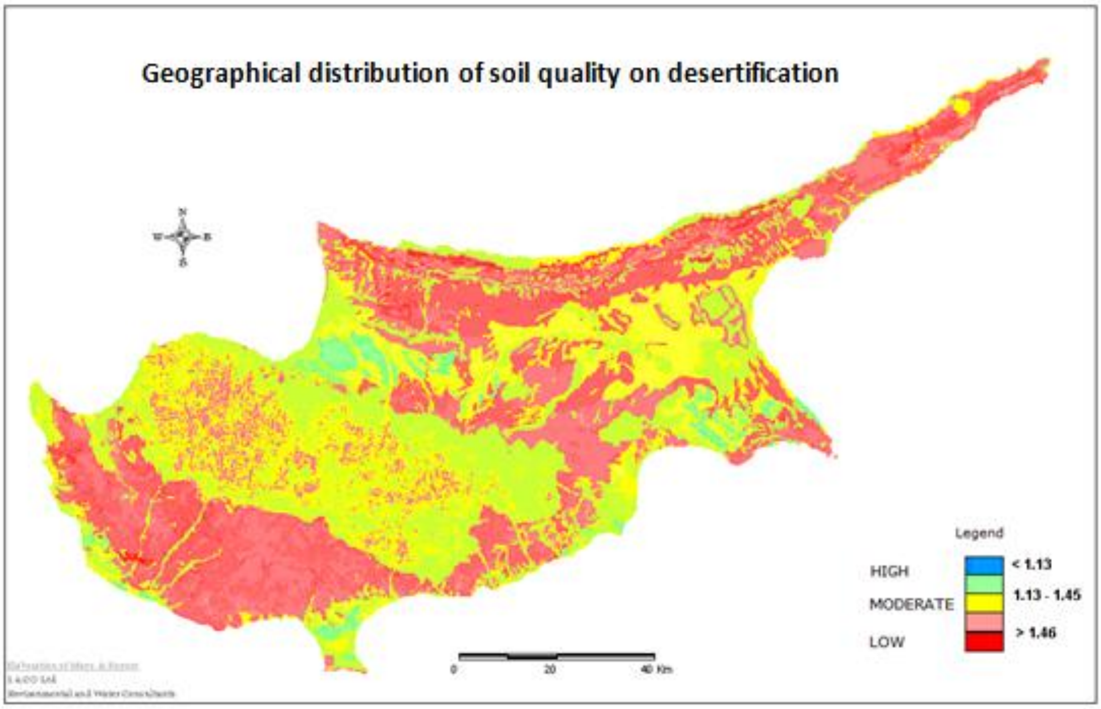


Figure 4-28: Geographical distribution of soil quality on desertification

In addition, some social aspects of Cyprus in combination with these physical characteristics of the island (topography, reduction of rainfall and poor on desertification and erodible soils) contribute to the deterioration of the phenomenon of desertification. One of the most important indicators for desertification is the overexploitation of water resources over the last 50-60 years with the reduction of water levels and water quality (various recorded levels of sea intrusion) due to the growing water demand and the increased groundwater use. Another parameter is the effects of the economic growth and development of the urban and coastal areas with the abandonment of the traditional agricultural activities and the aging of the rural population leading to the overexploitation of soil resources of the urban and coastal areas and the abandonment of the rural areas.

Climate change in Cyprus with the estimated 15% reduction of rainfall since 1970 and the more frequent presence of consecutive years of droughts have deteriorated the phenomenon of desertification.

Considering the above, the sensitivity of Cyprus to desertification can be characterized **very high**.

Exposure

Seriously eroded soils in semi-arid zones are found at sloping areas with excess higher than 12%. Hilly areas in Cyprus with slope excess of 12%, cover the 22% of the island. A large surface percentage of these hilly areas are covered by permanent vegetation (Figure 4-29) and are less affected by desertification. The most sensitive areas seem to be the plains, which are mostly covered by seasonal crops.

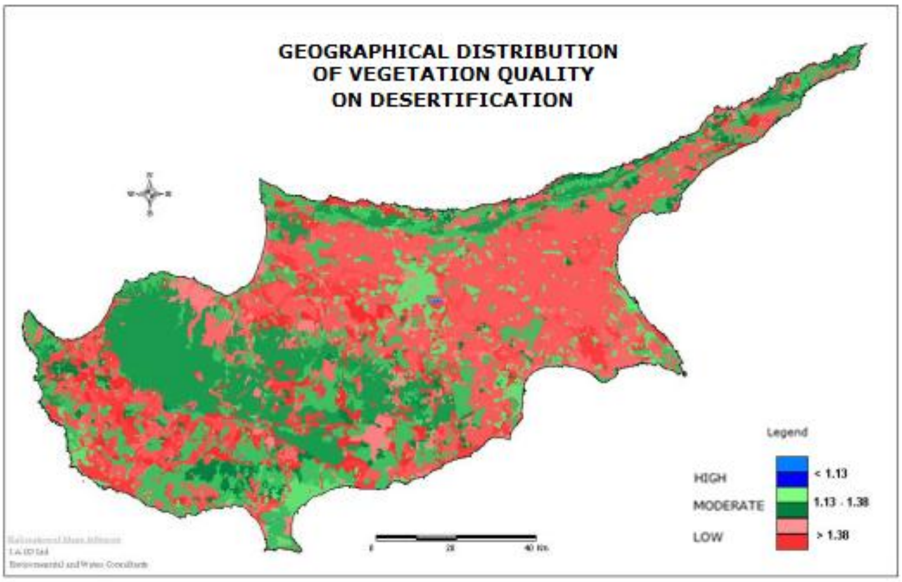


Figure 4-29: Geographical distribution of vegetation quality on desertification

Source: I.A.CO Ltd, 2007

Furthermore, the areas which are considered more prone to desertification are the urban and coastal areas due to the increased groundwater use and demand, soil sealing (Figure 4-8) and soil compaction (Figure 4-7), and the abandoned rural areas due to the economic growth and development of the urban and coastal areas are more prone to desertification (Figure 4-30).

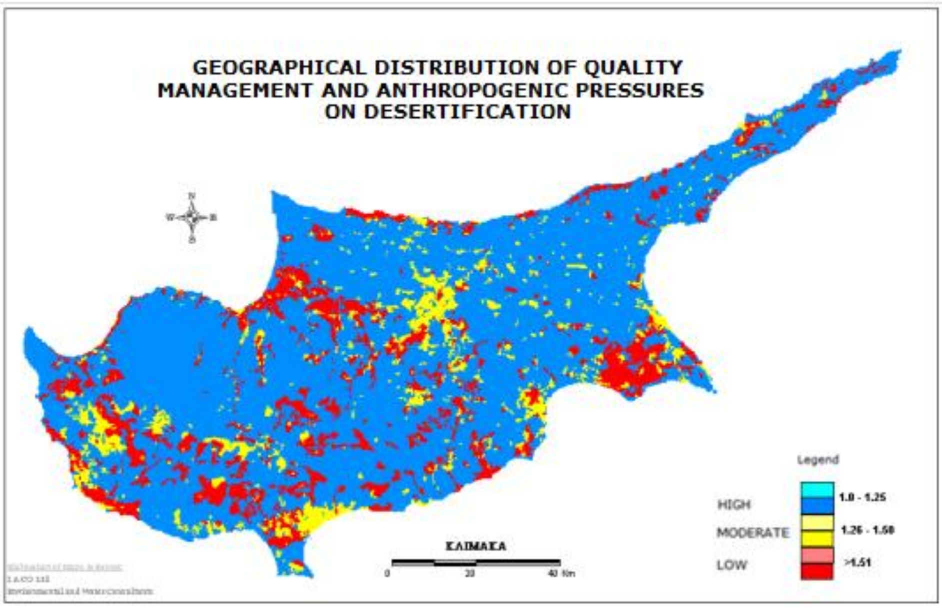


Figure 4-30: Geographical distribution of quality management and anthropogenic pressures on desertification

Source: I.A.CO Ltd, 2007

As shown in Figure 4-31 and Figure 4-32, desertification is characterised by high sensitivity. A surface area of 57% is characterized as “Critical”, 42,3% as “Fragile” and only 0.7% as “Potential” to desertification (I.A.CO Ltd, 2007). As a result, the exposure can be characterized as **very high**.

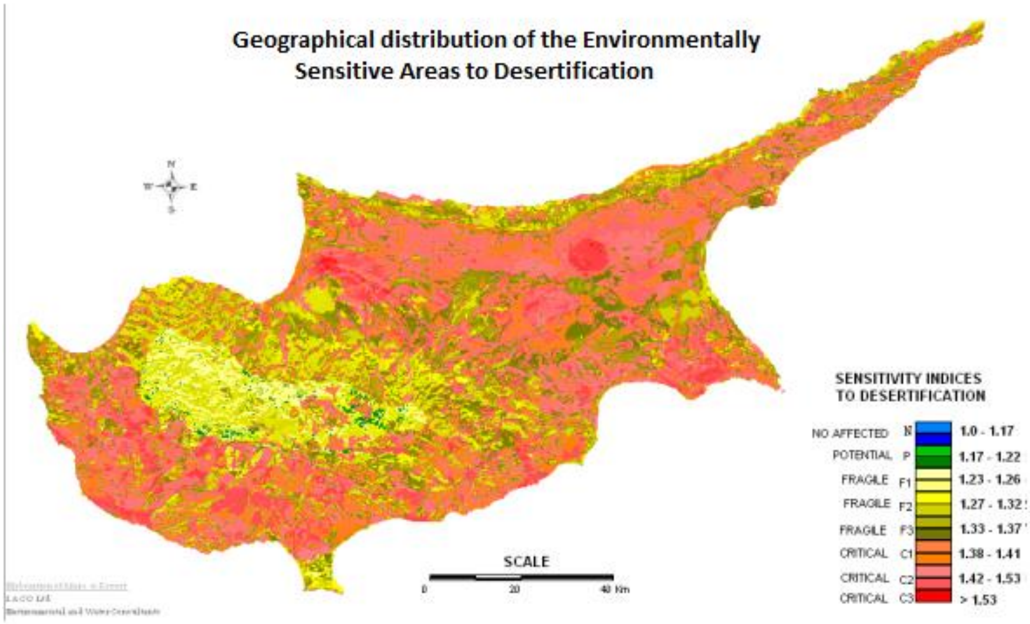


Figure 4-31: Geographical distribution of the Environmentally Sensitive Areas to Desertification

Source: I.A.CO Ltd, 2007

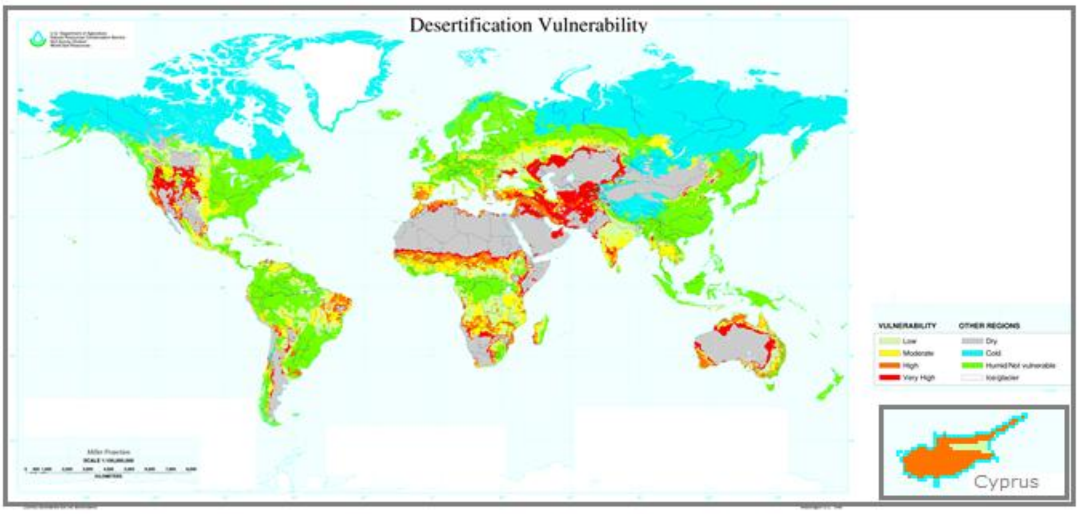


Figure 4-32: Map of global desertification vulnerability

Source: NRCS, 1998

4.4.5.2 Assessment of adaptive capacity

The resilience of soils against desertification includes parameters such as good soil quality and vegetation cover. In Cyprus, there is poor soil quality on desertification (Figure 4-28) while vegetation cover is restricted to the mountain areas (Figure 4-29). Provided that it requires the coordinated action from the majority of sectors (i.e. agriculture, forestry, water resources etc), there is a series of measures (see Table 4-10) ranging from legislation, to government works and private initiatives for the reduction of the escalation of the phenomenon. However, the phenomenon of desertification cannot be easily addressed in semi-arid climate types similar to Cyprus. For these reasons, the adaptive capacity is characterized as **limited to moderate**.

Table 4-10: Sectoral measures for the reduction of desertification in Cyprus

Measures per sector	Existing measures
Measures for desertification	Institutional measures: 1. Enforcement of the United Nations Convention to Combat Desertification with the law 23(III)/99. 2. Enforcement of the Directive 2006/12/EC and 91/156/EC with the law 215(I)/2002. 3. 106(I)/2002 about the control of the water and soil pollution
Measures for the agricultural sector	Technical measures: 1. Implementation of the Rural Development Program (RDP) (maintenance of terracing, reforestation, BATs etc.) 2. Incentives and encouragement for improved irrigation systems in the mountainous and semi-mountainous areas 3. Control on licensing new wells and control of abstraction 4. Control of the quality of irrigation water at the coastal and marginal Aquifers 5. Control of salinity of treated effluent used for irrigation
	Institutional measures: 1. Institutional measures and exploitation of various policies and grants from the EU.
	Confronting soil erosion 1. Confronting erosion and protection of soils with vegetative cover, terracing and contour tilling. Control of grazing in non agricultural lands
	Confronting drought and conservation of soil water 1. Selection of less water demanding cropping patterns and resilient to drought periods
	Measures for the reduction of losses and increase of soil water stored: 1. Continuation of encouragement for Improved Irrigation Systems
Measures for the forests sector	1. Expansion of State and private forests, refrain from undue use of wood and grazing, protection from fires and change of land use 2. Exploitation of RDP measures that promotes actions for the protection of forests from fires and reforestation of burnt areas 3. Increased measures, control and informing of farmers in regards to fire incidents caused by agricultural activities 4. Increased informing of forest visitors for the prevention of fires
	Land clearing (uprooting) of forest land for agricultural use:

Measures per sector	Existing measures
	1. Increase protection of existing forests but also their extension through forestation in suitable areas (barren, burnt, abandoned, degraded lands). This falls under the National Forest Program and the new forest policy.
	Over- grazing for animal husbandry: 1. Exercise of control on grazing permits in forest-covered lands on the basis of evaluations (result of special studies) in regard to the carrying capacity of each area and the degree of threat for desertification.
	Uncontrolled exploitation of Forests: 1. Accomplishment of quantitative increase and qualitative improvement of the wood reserve in the forests and other forest covered lands by systematic reforestation of burnt areas or reforestation of barren and degraded areas.
	Protection from illegal change of use: 1. Institutionalize ways and methods so that any change of land use in privately owned forest-covered lands is made only after an environmental impact assessment, particularly in relation to combating desertification.
	Confronting forest fires: 1. Continuous informing and sensitization of the public, farmers, visitors and hunters for the control of fires that are caused out of negligence
	Protection from damaging grazing: 1. Goats Law.
	Management and exploitation of forests: 1. Ensuring of the minimum disturbance to the environment by the methods and machinery for wood cutting and transport. 2. Effective planning, construction and maintenance of the road network in forest areas.
Protection of fauna	1. Systematic collection of population levels of species and classification as per the red register of IUCN. 2. Law 152(I)/2003 on the protection of wild birds and “controlled game”. 3. Law 153(I)/2003 on the protection and management of nature and wildlife 4. Law 17(III)/2001 on the Conservation of Migratory Species of Wild Fauna (Bonn Convention). 5. Law 20/1974 on the ratification of the Convention on the International Trade in Endangered Species (CITES) 6. Law 24/1988 on the protection of wildlife and natural habitats (Bern Convention). 7. Law 8 (III) / 2001 on the ratification the Ramsar Convention for the protection of internationally important wetlands 8. Law 4(III)/1996 on the ratification of the Convention on Biological Diversity (1992).

Measures per sector	Existing measures
(1992).Measures for the animal husbandry sector	1. Goats Law 2. Control with more severe fines on illegal grazing.
	Technical measures 1. Implementation of measures put forward in the Rural Development Program regarding infrastructure for animal husbandry.
Measures for the water resources sector	1. Water Framework Directive (WFD).
	For the quantity of water resources 1. Protection and replenishment of aquifers (development of strategic reserves). 2. Control of over abstraction of groundwater (reduction of pressure on coastal aquifers). 3. Desalination. 4. Reuse of treated effluent
	For the quality of water resources 1. Control of over abstraction and sea intrusion. 2. Protection of water from pollution from agricultural practices (pesticides, fertilizers). 3. Protection from urban effluent and uncontrolled disposal sites. 4. Protection from animal husbandry and industrial wastes.
	Institutional measures 1. Water Framework Directive 2. 13(I)/2004 about the protection and management of water. 3. 34/2002 about the nitrogen pollution of waters (based on the European Directive 91/676/EEC). 4. 42/2004 about the control of nitrogen polluted waters. 5. 41/2004 about the control of water pollution. 6. 517/2002 about the control of water pollution. 7. 407/2002 Good Agricultural Practices. 8. 56(I)/2003 about waste management. 9. 1/1971 about sewerage systems. 10. 108(I)/2004 about sewerage systems.

Measures per sector	Existing measures
	11. 772/2003 about urban wastewater. 12. 254/2003 about the nitrogen pollution of waterbodies. 13. 106(I)/2002 about the control of the water and soil pollution. 14. 45/1996 about the control of the water and soil pollution.
	Measures for irrigation 1. Design of improved irrigation systems.
	Measures for the domestic and industrial use of water 1. Information campaigns for the reuse of “grey water”. 2. Information campaigns for borehole drilling in marginal aquifers in urban areas for gardening purposes. 3. Information campaigns for water conservation and water awareness.
	Measures for aridity and drought 1. Use of improved irrigation systems
Measures for the coastal areas	1. Town Planning policy.
Socio-economic measures for combating desertification	1. Program for the enlightenment and information of organized groups (Information campaign, issue of pamphlets, seminars at sites with desertification problems) 3. Support programs for the agricultural sector (as included in the policy of the Department of Agriculture)
Measures for the elimination of SO_x, NO_x, VOCs and NH_4 emissions.	1. Directive 2001/81/EC on National Emission Ceilings for certain pollutants.

Source: Environmentally Sensitive Areas to Desertification Map, I.A.CO Ltd Environmental and Water Conasultants.

4.4.6 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of soil resources to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of soil resources against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for the soil resources in Cyprus are summarized in Table 4-11.

Table 4-11: Overall vulnerability assessment of soil resources in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Soil erosion (by wind and/or rain water)	Moderate to High (4)	High (5)	Limited to Moderate (2)	Moderate (2.5)
Landslides	Moderate (3)	Limited to Moderate (2)	Moderate (3)	None(-0.6)
Soil contamination	Limited (1)	Moderate (3)	Moderate (3)	None (-1.3)
Soil salinization - sodification	Moderate to High (4)	Moderate (3)	Limited to Moderate (2)	Limited to Moderate (1.5)
Desertification	Very high (7)	Very high (7)	Limited to Moderate (2)	High (5)

The most important impacts of climate changes on the soil resources of Cyprus are the extensive desertification and the soil erosion by rain water. In specific, the most important problem of Cyprus on soils seems to be the phenomenon of desertification, as 57% of the island is characterized as “Critical”, 42,3% as “Fragile” and only 0.7% as “Potential” to desertification. Soil erosion, which is actually one of the factors causing desertification, constitutes also key vulnerability for the soils resources of Cyprus mainly due to the intensive agricultural activities taking place and the increasing percentage of abandoned rural land. Soil salinization is the third vulnerability priority caused by the salinization of coastal aquifers and the irrigation with low quality (saline) water.

It must be mentioned that the characterizations used in this report are only qualitative and based on the available data for the soil resources of Cyprus in comparison with the rest of Europe. An important conclusion of this report, especially due to the extensive land degradation, is the necessity for further thorough research for the soil resources of the island.

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5 COASTAL ZONES

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Abbreviations and Acronyms

CAMP	Coastal Area Management Programme
DTPH	Department of Town Planning and Housing of the Ministry of Interior, Republic of Cyprus
ICZM	Integrated Coastal Zone Management
IPCC	Intergovernmental Panel on Climate Change
MAP	Mediterranean Action Plan
NGO	Non Governmental Organization
PWD	Public Works Department of the Ministry of Communications and Works, and Delft Hydraulics, Republic of Cyprus
WDD	Water Development Department (WDD) of the Ministry of Agriculture, Natural Resources and Environment, Republic of Cyprus
PAP/RAC	Priority Actions Programme/Regional Activity Centre
EIA	Environmental Impact Assessment

5.1 Climate change and coastal zones

Coastal zones are amongst the most dynamic natural environments on earth, including natural ecosystems such as coral reefs, mangroves, beaches, dunes and wetlands, in addition to important managed ecosystems, economic sectors, and major urban centers. Many people have settled in coastal zones to take advantage of the range of opportunities for food production, transportation, recreation and other human activities provided here. A large part of the global human population now lives in coastal areas and a considerable portion of global economic wealth is generated in coastal zones (Klein, 2002)

Coastal environments, settlements, and infrastructure are exposed to land-sourced and marine hazards such as storms (including tropical cyclones), associated waves and storm surges, tsunamis, river flooding, shoreline erosion, and influx of biohazards such as algal blooms and pollutants. All of these factors need to be recognized in assessing climate-change impacts in the coastal zone (McLean et al., 2001).

Human-induced global climate change and associated sea-level rise can have major adverse consequences for coastal ecosystems and societies (Klein, 2002). In the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Bijlsma *et al.* (1996) noted that climate-related change in coastal zones represents potential additional stress on systems that are already under intense and growing pressure. The IPCC concluded that although the potential impacts of climate change by themselves may not always pose the greatest threat to natural coastal systems, in conjunction with other stresses they could become a serious issue for coastal societies, particularly in those places where the resilience of the coast has been reduced (Klein, 2002).

5.2 Baseline situation

5.2.1 The coastal zone of Cyprus

Cyprus is the third largest island in the Mediterranean. It has a total shoreline of 772 km, of which 296 km are within the area on which the Government exercises effective control (38%), 404km are in the occupied part (52%) and 72km are within the British Military Bases (10%). The largest part of the country's territory can practically be considered as coastal zone and has a dominant influence on all of the island's landscape. Except for Nicosia, all other major towns are settled across the shoreline. In Cyprus there is no single legal or functional definition of the 'coastal zone' and/or 'coastal area'. There are three main widely used geographical definitions referring to 'coastal zone / area', each one related to the purposes of a different law and institutional context (Environmental Service, 2006):

- The Foreshore Protection Law defines the 'foreshore' as 'all lands within 100 yards (91.44 m) of the high water mark'. The foreshore area is public property falling under the jurisdiction of this Law.
- The New Tourism Policy (under the Hotel Accommodation Law and the Town and Country Planning Law – Countryside Policy, 1990) designates a 'coastal zone' with latitude of 3 km from the coastline for the purpose of regulating tourism development.
- The Coastal Protection Study of the Coastal Unit of the Ministry of Communications and Works has adopted a definition of the 'coastal strip' as the area of 2km from the coastline for the purposes of the survey of coastal erosion problems.

Based on the third of the aforementioned definitions, the coastal zone that extends 2 km inland from the coastline covers 23% of the country's total area, in which about 50% of the total population lives and works and 90% of the tourism industry is located. Coastal areas generate by far the largest source of household income, as well as other major activities and most of the urban development. The rapid population growth and sprawl of building development at the suburban edges of the urban areas are the dominant features of urbanization in Cyprus. In the period 1981-2001 the urban population growth (population growth within the areas covered by the Local Plans for the main towns) reached 46% compared to a total population growth of 35%. Within the Local Plan areas, population growth in the suburban areas was more than twice the growth of population in the core urban areas that is 68% and 26% respectively. The 95% of all licensed tourism hotel accommodation capacity are within the coastal zones. Also urban population in the Local Plan areas of the coastal towns (Limassol, Larnaca and Paphos) presented a much higher growth than in the Nicosia Local Plan area in the period 1981-2001 e.g. 55% and 35% respectively. A much stronger contrast is revealed by the disparity in the growth of coastal rural areas (45%) and the inland rural areas (8%) (Environment Service, 2006).

5.2.2 Regulatory & managerial regime

Cyprus has a well-developed planning legislation, focusing on guiding development and regulatory controls and paying attention to the coastal area for obvious reasons. Parallel policies for the management of coastal resources (fisheries, marine habitats, water, agriculture, tourism, wastewater and solid waste, road traffic, etc.) are designed and implemented by competent authorities under the Cypriot legal and administrative framework. The main competent Authorities which activities are related to the coastal protection are the following (Environment Service, 2006):

- The Department of Environment of the Ministry of Agriculture, Natural Resources and Environment, focal point for the EU Integrated Coastal Zone Management (ICZM), has proceeded with the initiation of a Coastal Area Management Programme (CAMP), the implementation of the Bathing Waters Directive, the promotion of 'Ecolabel' for touristic accommodation units and the preparation of management plans for 'Natura 2000' sites, some of them being coastal / marine.
    - CAMP Cyprus was initiated by the PAP/RAC of the Mediterranean Action Plan (MAP) in close cooperation with the Cyprus Government. The duration of the program was two years (2006-2008). More details on the link of the website of the Department of Environment
    - After the annual national inspection visits to several beaches and the appropriate evaluation, the International Jury has decided to award the Blue Flag to 56 beaches in Cyprus for the year 2011.
    - Cyprus is fully implementing the 'Bathing Waters Directive'. A total number of 113 coastal bathing areas are being monitored fortnightly during the summer season (May to October). The report for 2011 has established the excellent quality of the bathing waters in all monitored areas.
    - The EU Eco-label for touristic accommodation units comprises another means towards the sustainability of tourism. There is great interest for the obtainment of this label by touristic accommodation facilities. At the end of 2005 the first Ecolabel was awarded to a coastal hotel.
    - The European Commission for the 'Natura 2000' network has approved 61 areas that are protected for their wildlife and habitats value. Ten (10) of them are within the coastal zone. The preparation of their management plans for some of them was initiated in 2005.
- The Department of Town Planning and Housing (DTPH) of the Ministry of Interior is responsible for the following (Environment Service, 2006):
    - The regulation of development through the implementation of Development Plans (Local Plans, Area Schemes) and the Statement of Policy

for the Countryside that covers all types of land uses (residential, commercial, tourism, industrial, open space, protected areas, etc.) and

  - The exercise of development control in all parts of the island based on the requirement for obtaining planning permission for all building developments. During 2005 the Local Plan for 3 main coastal towns were re-examined / revised. The main framework of the planning legislation is the Town & Country Planning Law of 1990. The 'Island Plan', a statement of the broad national strategy on regional spatial planning with strong links to overall economic and social policy is inactive due to the political problem of Cyprus.

- The Coastal Section of the Public Works Department (PWD) of the Ministry of Communications and Works, and Delft Hydraulics is responsible for the construction of coastal defense works for the protection of the coast from erosion and other risks (Environment Service, 2006).
- The Water Development Department (WDD) of the Ministry of Agriculture, Natural Resources and Environment works on the protection of water resources from coastal development, such as on the impacts from over-pumping, sea water intrusion, nitrate pollution and leaching of nitrates into the sea. The water management policies includes among others the construction of dams and irrigation networks ,wastewaters treatment plants and irrigation scheme with advance treated wastewaters, and the more recently adopted policies with respect to desalination and replenishment of aquifer (Environment Service, 2006).

5.2.3 Physical environment

A description of the physical environment regarding the coastal zones of Cyprus, related to the following thematic fields are given below:

- Geographical position and geology of the island where a brief description is given regarding the position of Cyprus as part of the East Mediterranean Basin.
- Coastal ecosystems where the morphology of the coastal zone is described along with a brief report concerning the biodiversity of these areas.

5.2.3.1 Geographical Position & Geology

The coastal plain around the island is very narrow (0.5-5 km wide). Elevated marine terraces are found bordering along the coastal plain. At least six (6) levels of old marine terraces can be distinguished. The Plio-Pleistocene calcarenites and the beach deposits gravel and sand -

form along the coastal plain, thin (0.5-10 m) discontinuous groundwater bodies of local importance. Their extent and thickness is controlled by the configuration of the underlying impermeable base (Palaeogene to Miocene sediments consist of marls, chalks and chalky marls) (Avraamides, 2001).

In particular, the south-east coast of Cyprus is characterized a Mesozoic to Tertiary basement of calcareous and igneous materials. The coastal area, which is often rocky, is characterized by accumulations of pebble and gravels with few tiny and poor sandy beaches. The material that has accumulated at these beaches originates either from nearby rocks or from the inland bedrock. The elevated marine terraces are composed of conglomerate with well-rounded pebbles, mostly of igneous origin (Loizidou, 2002).

5.2.3.2 Coastal environment

The Cyprus coastline varies at a large degree, ranging from steep inaccessible cliffs and ragged rocky shorelines with sea caves to gentle sloping sandy beaches fringed with sand dunes. The coastal zone is characterized by rich wildlife, long and small beaches, open areas, cliffs, capes, harbors, sand dunes, accumulations of pebbles and, in general, marine and shore areas of prime ecological and scientific value. The portion of the coastal area that is protected covers approximately 14% of the island coastline (Demetropoulos, 2002).

Sandy beaches are predominant in the large bays of Cyprus, Famagusta, Larnaca, Limassol, Polis Chrysochou and Morphou. These long beaches often grade into shingle beaches at one end of the bay depending on the wave-generated littoral drift. There are also pocket beaches in many rocky shores, which can be extensive (Demetropoulos, 2002).

Sandy beaches on the island have different properties. They vary not only in the chemical and physical (grain size, etc) characteristics of the sand, but also in their profile, depth and stability. Beaches on the west coast of the island are exposed to the pounding action of large waves. They have higher profiles and are constantly on the move (Demetropoulos, 2002).

Shingle beaches are often the poorest of the shoreline habitats, as practically nothing survives the grinding action of such beaches during periods of rough weather. They are extensive in Episkopi Bay and in parts of Morphou Bay as well as in stretches of the south coast between Limassol and Larnaca and between Petra of Romiou and Paphos (Demetropoulos, 2002).

Rocky shores in Cyprus also present great variations. The hard limestone shores, which predominate, are the most notable and ecologically interesting ones. There are several areas with such coastline - much of the south-eastern part of the island, all the way from Cape Pyla to Paralimni, is of such rock (with several pocket beaches) - as it is part of Akamas - and most of the Kyrenia coastline from Cape Kormakiti to Cape Andreas (again with many sandy pocket beaches). The occurrence of what is known as the Vermetus reef or shelf is what is most interesting in such areas, from an ecological point of view. The shelf can be narrow 1 metre or so or it may be several metres wide in exposed coasts. Extensive shallow rock pools are created between the reef and the shore, with some deeper rock pools eroded into the shelf. The vertical wall, which often drops off the shelf into deeper waters, is only partly exposed to air and that only during low spring tides (Demetropoulos, 2002).

Salt lakes, sand dune and sea cliff habitats are included in this broad habitat category. Salt lakes are distributed around the east and south coasts. They are currently threatened by drainage and nutrient enrichment from agriculture and domestic effluents. Salt lakes are stands of vegetation consisting of a small number of specialist species that can tolerate the salt content of the substrate, occurring along sheltered coasts, mainly on sand or mud, and which are flooded periodically by the sea (Department of Environment, 2010).

Sand dunes are hills of wind blown sand that have become progressively stabilized by a cover of vegetation. Sand dunes are species-rich habitats for plants and invertebrates and can be described as coastal hills formed at the back of a beach by deposits of materials, varying on their origin, amount, type and size. These hills are classified further in several dune types, according to their shape and development, which are then synthesized in various biogeomorphic types of dune systems. Between sea and land, these complex geomorphotopographic ecosystems show a notable variation of several factors, such as nutrient availability, soil salinity, aerial salt deposition, water conditions, organic compound, soil texture and pH. Such factors constitute a variety of microenvironments and influence the presence of the species and the vegetation type and lead to the great biodiversity of the sand dune ecosystems (Department of Environment, 2010).

Coastal sand dunes are among the most vulnerable habitats of Cyprus and are subject to high-intensity recreational and other uses**.** There are numerous types of anthropogenic pressures and impacts on the sand dune ecosystems of Cyprus. The majority of these are local activities influencing each site (e.g. trampling, driving and grazing). Although others are external, occurring at some distance from the dune site, they can affect the structure and function of the systems by reducing the delivery of sediment (e.g. by dam construction) (Department of Environment, 2010).

Dune systems are in a constant state of change and maintaining their natural dynamism is essential to ensure a favorable conservation status. Impacts on sand dune habitats include (Department of Environment, 2010):

- Removal of beach material, which exacerbates the process of natural erosion,
- Motorized recreational activities and high visitor pressure on some sites,
- Recreational activities and pressure for development.

Sea cliffs are distributed in a limited extent in coastline. A number of sea cliffs are very important bird-of-prey colonies, as well as seabird colonies. Despite their relative inaccessibility, pressures and threats to the habitat include recreation, tourist visit and housing and dumping. In some cases, coastal protection works interfere with the natural functioning of sea cliffs, particularly soft cliffs prone to erosion (Department of Environment, 2010).

High cliffs with sea caves can be found in several areas in Akamas, Akrotiri and elsewhere. Some of these caves were inhabited by the Monk Seal and some still are (Dendrinos and Demetropoulos, 1998).

5.2.4 Anthropogenic environment – Human pressures

The coastal zone in Cyprus is densely populated and therefore environmentally vulnerable. It is subjected to increasing pressures from a number of sources (e.g. industrial development, urban sprawl, exploitation of marine resources, tourism, etc.). There is, thus, an urgent need to integrate the many uses of coastal resources so that they can be rationally developed in harmony with one another and with the environment. These uses along with the anthropogenic impacts include (Ramos-Esplá et al., 2007):

- Tourism and recreation/leisure areas.

  These uses are representing the principal activity in the Cyprus coastal area, with significant increasing trends during the past years. The respective infrastructure, activities and impacts include:

  - Tourism accommodations.

    As much as 95% of tourism accommodation is located in the urban coastal towns and the smaller tourism settlements of Ayia Napa, Paralimni and Polis. The “narrow” tourism sector of hotels and restaurants accounts for 20% of the Gross National Product, whilst the wider tourism sector, including parts of the agricultural, trade and financial services sectors closely linked to tourism demand is estimated to account for as much as 70% the Gross National Product.

  - Beaching.

    The respective uses are referring to sunbathing, bathing and swimming; nautical sports (surfing, nautical ski, towed parachuting, sea-scooters (jet-skis) etc.). The major impacts from these uses are overfrequentation and habitat destruction (sand replenishment).

  - Nautical development.

    The respective uses are referring to marinas, boating, mooring. The major impacts from these uses are hydrodynamic alterations and habitat destruction (marinas, dredging, mooring, silting); disturbance of turtle nesting.

- Living resources and marine biodiversity.

  The respective uses are referring to diving (snorkelling, scuba); bait and another fauna collection. The major impacts from these uses are habitat destruction (turn over the blocks, collection of sea dates and other species, 'souvenirs' as nacres); scuba erosion (mainly in the caves).

- Educational, research and conservation uses.

  These uses represent positive activities which permit the protection of the coastal and marine areas. Some areas have been proposed as marine protected areas (Cape Greco, Moulia Rocks, Akamas Peninsula, Polis/Yialia etc).

- Coastal urban development.

  The demand for new buildings represents a potential coastal threat in the case that there is lack of rational planning and management of this important resource. The respective infrastructure along with their uses and their relative impacts include:

  - Buildings and roads.

    The largest urban centers in Cyprus, except Nicosia, are coastal (Limassol, Larnaca and Paphos) accounting for 48% of the total population and 58% of the total urban population, with Nicosia, the capital, accounting for the remaining 42% of the urban population.

    Employment is likewise concentrated in the coastal areas. 100,000 out of 149,000 non-agricultural jobs are concentrated in the coastal towns and in the tourism area of Ayia Napa and Paralimni. 15,600 in the hotel and restaurant sector, 12,500 in the financial sector and 21,000 in the trade sector.

    The respective uses are referring to land reclamation, littoral roads, promenades and villas very close to the coast, lights, littoral overfrequentation. The major impacts are related with destruction and degradation of sand dunes and other sensitive coastal and marine habitats.

    The broad coastal belt of Cyprus, stretching from Paphos in the south west to Limassol, Larnaca and Paralimni in the east, is connected by the second heaviest used highway, second to that connecting Nicosia to the coastal highway.

    The population of the rural coastal settlements (about 20 in number, including Ayia Napa and Paralimni) are the largest and fastest growing rural settlements, accounting for about 25% of all rural population, growing at nearly 2.0% per annum, higher than the rate as the urban population and twice as high the average growth rate of the inland rural settlements (about 275 in number).

- Industrial activities.

  The impact of industrial activities via localizing in some coastal areas (fish cages, desalination plants, power plants) can be important. In particular, the respective activities are related with the following types of infrastructure:

  - Aquaculture.

    The respective uses are dealing with the development of sea fish cages for the fish rearing and fish processing prior to market exploitation. The major impacts are including organic (including nutrients) and antibiotic pollution (habitat degradation) and the invasion of undesired living species.

  - Desalination plants.

    The respective uses are dealing with the desalination of seawater. The major impacts derive from the release of untreated brine into the sea (osmotic alterations, chemical pollution habitat and biodiversity degradation) and high energy consumption related to emissions.

  - Power generation plants.

    The respective uses are dealing with electricity generation using the seawater for cooling. The major impact is the increase of seawater temperature causing metabolism and biological alterations.

  - Waste treatment.

    The respective uses regarding waste treatment facilities are related with the management of domestic solid waste and wastewater, their treatment and disposal or use. The major impacts from these activities involve organic, nitrogen and phosphate pollution of surface and ground waters, sea eutrofication, algae blooms, low quality of seawaters and degradation of coastal ecosystems. In particular at Paralimni and Ayia Napa, they are occurred high algae blooms during summer periods.

  - Wastewater treatment plants.

    The island of Cyprus has five (5) waste water treatment plants that are located along the coastline. These plants are serving Larnaca, Paralimni, Ayia Napa, Limassol and Paphos.

  Overall, the main industrial activities across the Cypriot coastline are located at the following plants (Constadinides, 2002):

  - Limassol wineries,

    - Larnaca petrol refinery,
    - Moni and Vassilikos cement plants (near Limassol) and
    - Power plants of Moni and Dhekelia (near Larnaca).

- Maritime traffic and transport

  This activity is targeted mainly around the commercial ports (Larnaca and Limassol areas). The respective uses are related with traffic, mooring areas and the construction of pipelines for gas or oil. The major impacts are including hydrodynamic alterations (enlargement of actual ports); habitat destruction (dredging, mooring, silting); invasion non-indigenous species (ballast water, fouling) and oil spills.

- Airports.

  The two international airports are on the coast (Larnaca and Paphos) and the two ports (Limassol and Larnaca).

In Table 5-1 the main types of coastal zones in Cyprus and their respective length are presented.

Table 5-1: Development Profile of the Cyprus coastal zone

Type of Coastal Zone's Area	Length of Coastal Zone in km	Percentage of Coastal Zone Area in Total Coastal Zone's Length (%)
Urban coastal areas (urban tourism and infrastructure)	90	30
Tourism driven development areas (expanding tourism development in areas with designated tourism development zones with pockets of agricultural land)	45	15
Rural coastal areas (mainly agricultural area mixed with increasing holiday homes)	106	36
Protected coastal areas	55	19
Total length of coastal zone of the area under government control	296	100
Sovereign Base Areas	72	
Northern coastal area	404	
Total coastal length of Cyprus	**772**	

Source: Coccossis et al., 2008

The human pressures on the coastal environment are expected to be increased due to the population increase. In addition, the following main population growth indicators for the period 1981-2001 sum up the coastal concentration pattern and the extent of coastal pressures for both urban and rural residents (Coccossis et al., 2008):

- Total population growth: 35%;
    - Total urban population growth: 46%;
        - Coastal urban growth: 55%;
        - Inland urban growth: 35%;
    - Total rural population growth: 15%;
        - Coastal rural growth: 45%;
        - Inland rural growth: 8%.

On the basis of all the aforementioned information, it is clearly indicated that anthropogenic pressures on Cyprus coastal zone are not only extensive, but they also have increasing trends.

5.3 Impact assessment

The most notable reported climatic changes affecting coastal zones are the sea level rise, the rise of mean temperatures, the decrease in precipitation, the increase of sea water intrusion and the increase of extreme weather events. Climate change is expected to affect the coastal areas of the Eastern Mediterranean area in a variety of ways. Many Aegean-Levantine coastal regions are expected to be exposed to an increasing risk of flooding and erosion. Low-lying coasts are particularly vulnerable, notably delta areas, lagoon coasts, tidelands and some islands. Additionally, cliffs and beaches are vulnerable to erosion, estuaries are vulnerable to increased salination, and coastal groundwater aquifers are vulnerable to shrinkage and saltwater intrusion (Parari, 2009).

The correlation of the climate change factors with the impacts on the coastal zone of Cyprus is presented in the following table.

Table 5-2: **Relationship between observed climate changes and impacts on the coastal zones sector**

Climate changes	Impacts on coastal zone
Sea level rise	– Coastal Erosion, loss of beach area, increase of inundation canals – Decrease of the total coastline length – Inundation, flood and storm damage – Seawater Intrusion, altered water quality/salinity, soil Salinity, losses and/or changes of coastal ecosystems
Increase in the frequency and intensity of extreme weather events	– Damages on the coastal human environment, increased water levels and wave heights, risk of flooding, inundation, increase or decrease storm surge occurrence – Increased cross-shore erosion, removal of sediment supply, degradation of coastal ecosystems – Re-orientation of beach plan form, increase or decrease longshore transport
Sea water temperature rise	– Increased stratification, algal blooms, degradation of coastal ecosystems, loss of natural attractions and species

The impacts of climate change on the coastal zone of Cyprus are further analyzed in the following sections of this chapter. These are grouped in three impact categories, namely:

- Coastal storm flooding and inundation
- Coastal erosion

- Degradation of coastal ecosystems

5.3.1 Coastal storm flooding and inundation

Scientists project an increase in the frequency of large storms in the coming century. At the same time, sea-level rise would increase the area likely to be inundated by these coastal storms because storm flooding would reach higher inland elevations.

The return period for heavy rainfall events may decrease in many parts of the world, given global warming (Gordon et al.,1992). This would intensify flooding, particularly in low-lying coastal areas where the base level will be simultaneously increasing due to sea-level rise. Climate change may also lead to a change in the frequency and intensity of storms, extreme precipitation and runoff events. In addition to wind damage, coastal storms cause storm surges which flood low-lying coastal areas and allow destructive wave action to penetrate inland (Nicholls & Hoozemans, 1996). The degree to which coastal land is at risk of flooding from storm surges is determined by a number of morphological and meteorological factors, including coastal slope and, wind and wave characteristics (Sterr et al., 2003).

Inundation is the permanent submergence of low-lying land. The primary mechanism at any location depends on the geomorphology of the coast. Many other factors apart from sea-level rise can play a part in determining land loss (*e.g.*, vegetation, sediment supply) (Sterr et al., 2003). Low-lying coastal areas such as deltas, coastal wetlands and coral atolls may face inundation as a result of sea-level rise. Land loss resulting from inundation is simply a function of slope: the lower the slope, the greater the land loss. (Sterr et al., 2003)

'Coastal squeezing' is another major problem presented by sea flooding. This term refers to coastal morphologies that would otherwise readjust to the rising sea by retreating landwards, but are currently obstructed by physical or anthropogenic barriers, such as coastal infrastructure. Sand dunes, or wetlands lying in front of built up areas are such examples. As a quite large percentage of Cyprus' coastal zone is developed, coastal squeezing can become a real issue for certain areas (Parari, 2009).

Pluviometrical data from the meteorological station in Nicosia (1930-2007) show an increase in the intensity and quantity of precipitation of 37-49% for the period 1970-2007 in comparison with the period 1930-1970 for a duration of precipitation between 5 minutes and 6 hours (Pashiardis, 2009). However, Cyprus has not experienced any severe floods from the sea in the past. Also in the coming years, the island is not expected to become very vulnerable to sea flooding (EC, 2009).

The impacts of sea flooding, storm surges and tidal waves on the built environment of coastal zones are analyzed in detail in Section 0: Infrastructure.

5.3.2 Coastal erosion

Coastal erosion represents the physical removal of sediment by wave and current action (Sterr et al., 2003). Many coasts are experiencing erosion and ecosystem losses, but few studies have unambiguously quantified the relationships between observed coastal land loss and the rate of sea-level rise (Zhang et al., 2004; Gibbons and Nicholls, 2006, Nicholls et al., 2007). Coastal erosion is observed on many shorelines around the world, but it usually remains unclear to what extent these losses are associated with relative sea-level rise due to subsidence, and other human drivers of land loss, and to what extent they result from global warming (Hansom, 2001; Jackson et al., 2002; Burkett et al., 2005; Wolters et al., 2005; Nicholls et al., 2007).

Bird (1993) argues that with global warming and sea-level rise there will be tendencies for currently eroding shorelines to erode further, stable shorelines to begin to erode, and accreting shorelines to wane or stabilize. Local changes in coastal conditions and particularly in sediment supply may modify these tendencies, although Nicholls (1998) has indicated that accelerated sea level rise in coming decades makes general erosion of sandy shores more likely (McLean et al., 2001).

Erosion constitutes a greater threat than flooding in Cyprus, especially for the sandy and gravel beaches of the island such as the coastlines of Larnaca and Limassol which have been suffering from severe erosion during the last 30 years. The phenomenon of coastal erosion in Cyprus is mainly attributed to human interventions which in some cases are triggered by natural causes associated with climate change. Examples of human activities causing coastal erosion in Cyprus are (Özhan, 2002):

- Sand and gravel mining
- Decreasing the sediment transport efficiency by lowering water discharges due to decreased water availability
- Cutting off the sediment transport by damming the rivers. Decreased precipitation and droughts in Cyprus forced the government to increase at the degree possible rainwater storage with the construction of numerous dams aiming to eliminate water losses to sea and increase water availability. However, the damming of rivers had as a result to cut off sediment transport through rivers

- Illegal construction of coastal defence works by hotel owners for the protection of the beach located in front of their properties without taking into account the impacts of these works to the near-by beaches
- Alteration of the usual pattern of coastal currents and the associated sediment transport along and across the shoreline, due to man-made coastal structures and urban development too close to the shoreline,
- Land subsidence due to anthropogenic effects.

This winter (2012), the naturally sandy beach of Coral Bay in Peyia Paphos has been badly damaged by storms that much of the sand has gone. Coral Bay, is a popular destination with both tourists and locals, who flock to the area to enjoy the blue-flagged sandy beach and sparkling waters. But according to Peyia councilor Linda Leblanc, the forthcoming summer season looks bleak. “Almost all of the sand has gone from the beach as we had particularly bad storms this year,” she said. “There are often rough storms during the winter period, but this year the devastation seems to be worse” (Cyprus-mail, 2012).

Although no studies have accomplished yet to clarify whether coastal erosion in Cyprus is also attributed to climate change (Shoukri and Zachariadis, 2012), it is expected that future climate change impacts could exacerbate coastal erosion in Cyprus (EC, 2009).

5.3.3 Degradation of coastal ecosystems

Overall, the impact of climate change for coastal ecosystems and wetlands in Cyprus is not known yet, as the relevant research in this domain is still lacking (EC, 2009). However, the impacts are expected to be long term and mostly affected by temperature, sea level rise and reduction of the available sediment and biomass for the growth of ecosystems.

The main danger that may affect coastal ecosystems in the next years is the increase of soil salinity due to sea water intrusion, irrigation with low-quality (saline) water and inadequate field drainage (Avraamides, 2001). Excessive rates of groundwater withdrawal have resulted in a large drop in the water table in the coastal ecosystems of Cyprus. Consequently, seawater has intruded into the respective aquifers. With growing populations in coastal regions, saltwater intrusion is expected to occur more widely, and may enhance the rate of saltwater infiltration. Also, sea level rise is expected to exacerbate intrusion of saline water into the fresh groundwater aquifers of the coastal areas. Increasing temperature is also expected to enhance soil evaporation, increasing soil salinity in this way and therefore, leading to alteration in biodiversity habitats.

Coastal wetland ecosystems, such as saltmarshes and mangroves or saltcedars, are especially threatened where they are sediment starved or constrained on their landward margin (Nicholls et al., 2007).

5.4 Vulnerability assessment

In this section, the vulnerability of coastal zones to climate change impacts is assessed in terms of their sensitivity, exposure and adaptive capacity, based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which coastal zones are affected by climate changes, exposure is the degree to which coastal zones are exposed to climate changes and their impacts, while the adaptive capacity is defined by the ability of coastal zones to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The indicators used for the assessment of sensitivity, exposure and adaptive capacity of Cyprus coastal zones to climate change impacts are summarized in Table 5-3.

Table 5-3: Indicators used for the vulnerability assessment of climate change impacts on the coastal zones of Cyprus

Vulnerability variable	Selected indicators
Coastal storm flooding and inundation	
Sensitivity	– Coastline length of low-lying areas and percentage of the total coastline – Vegetation cover* – Sediment supply* – Slope* – Proportion of the coastline occupied by urban and tourist infrastructure
Exposure	– Sea level rise – Coastal floods – Frequency and intensity of rainfall, storms and waves at the coastal zones*
Adaptive capacity	– Hard defense works (seawalls, revetments, breakwaters, groynes) – Fishing shelters – Artificial reefs – Foreshore Protection Law
Coastal Erosion	
Sensitivity	– Coastline length of low-lying areas and percentage of the total coastline – Proportion of sandy and gravel beaches
Exposure	– Sea level rise – Length of eroded coasts and percentage of the total coastline – Frequency and intensity of rainfall, storms and waves at the coastal zones*

Vulnerability variable	Selected indicators
Adaptive capacity	– Hard defense works (seawalls, revetments, breakwaters, groynes) – Fishing shelters – Artificial reefs – Beach nourishment – Prohibition of sand and graveling mining
Degradation of coastal ecosystems	
Sensitiviy	– Estuaries, coastal aquifers – Areas of high biodiversity value – Length of the coastline with important ecosystems (protected areas) and percentage of the total coastline
Exposure	– Degradation of coastal ecosystems* – Sea level rise – Salinization of coastal aquifers – Coastal erosion
Adaptive capacity	– Coastal defense structures – National list of habitats designated as 'special areas of conservation'

*There were no data regarding this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from "none" to "very high".

In the sections that follow, the vulnerability is assessed for each of the impact categories presented in Section 5.3:

1. Coastal storm flooding and inundation
2. Coastal erosion
3. Degradation of coastal ecosystems

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability. In case additional data are provided by the competent authorities of Cyprus, the vulnerability of the sector could be re-assessed.

5.4.1 Coastal *s*torm flooding and inundation

5.4.1.1 Assessment of sensitivity and exposure

Sensitivity

Cyprus as an island, is sensitive to sea flooding all along its coast, with more sensitive being the low-lying areas. It is estimated that, less than 5% of Cyprus coastline is comprised of low-lying areas[17] (EC, 2009). The main area in Cyprus identified as low-lying is located in Larnaca.

The elevation of an area combined with a number of other factors, such as vegetation, sediment supply and slope, determine the risk of inundation. Although a series of case studies have been carried out for many of the coasts in Cyprus providing some of the data required to assess risk of inundation, there is no clear picture for the whole island.

For accessing the risk of coastal squeezing, that is the obstruction of coastal morphologies to retreat landwards due to physical or anthropogenic barriers, the proportion of the coastline occupied by urban and tourist infrastructure was used as an indicator. As it can be seen from Table 5-1, approximately 45% of the coastline is occupied by urban and tourist areas (30% and 15% respectively). However, it must be noted that their proximity to the coast varies from area to area. In general, it can be said that in urban areas the main barriers are constructions such as harbours or roads while for the case of tourist areas the anthropogenic barriers are mainly hotels, restaurants, etc.

Taking into account the available data on the above mentioned indicators, it can be said the sensitivity of Cyprus coastal zone to sea flooding is **moderate to high**.

Exposure

For the assessment of the exposure of Cyprus' coastal zones to storm flooding and inundation, data on the sea level rise and on the flooding events in Cyprus will be used as indicators. Several climatic factors which could also be used as exposure indicators are the frequency and intensity of rainfall, storms and waves that the coastal zones of Cyprus are exposed. However, in absence of concrete data on the last indicators the assessment will be based on the first two indicators.

Sea level rise in the Mediterranean Sea is not expected to be as high as in the oceans. Especially for the case of Cyprus, the sea level rise is expected to be moderate (EC, 2009). Furthermore it must be added that, based on archaeological data, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm per year. This uplift will counteract global sea-level rise and given a global rise in sea level of 0.5m by 2100, relative sea-level

[17] Low-lying areas are defined as 10 km of coastal zone below 5 metres elevation

rise in Cyprus will be in the range 0.4-0.5m (Nicholls and Hoozemans, 1996). The sea level changes in Cyprus as observed during the period between 1993 and 2000 show an increase of 5-10 mm/year (Figure 5-1).

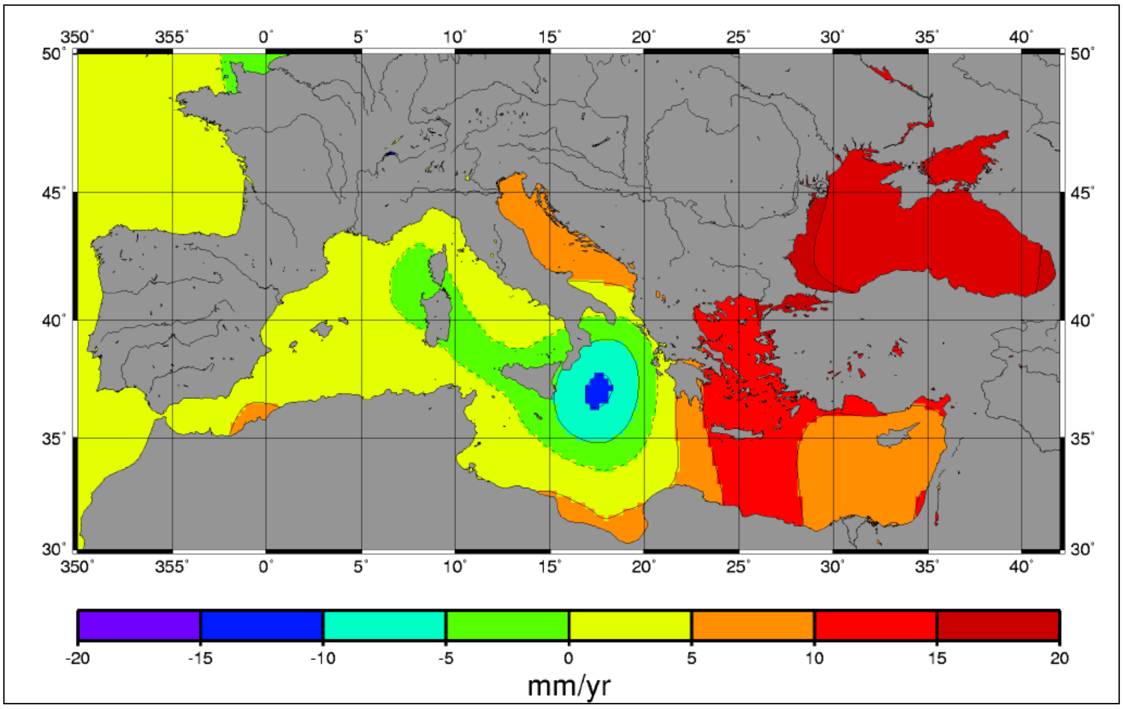

Figure 5-1: Mediterranean basin sea level changes between 1993 and 2000

Source: Ministry of Environment of Lebanon, 2011

According to the Water Development Department, the recorded floods in Cyprus for the period 1859-2011 are characterized as urban floods (37%), flash floods (20%), river or fluvial floods (16%), pluvial or ponding floods (13%), or a combination of the above (Water Development Department, 2012). However, none of the recorded flooding events have been characterized as sea or coastal floods. The following map presents all recorded flooding events in Cyprus as well as the areas with potential significant flood risk.

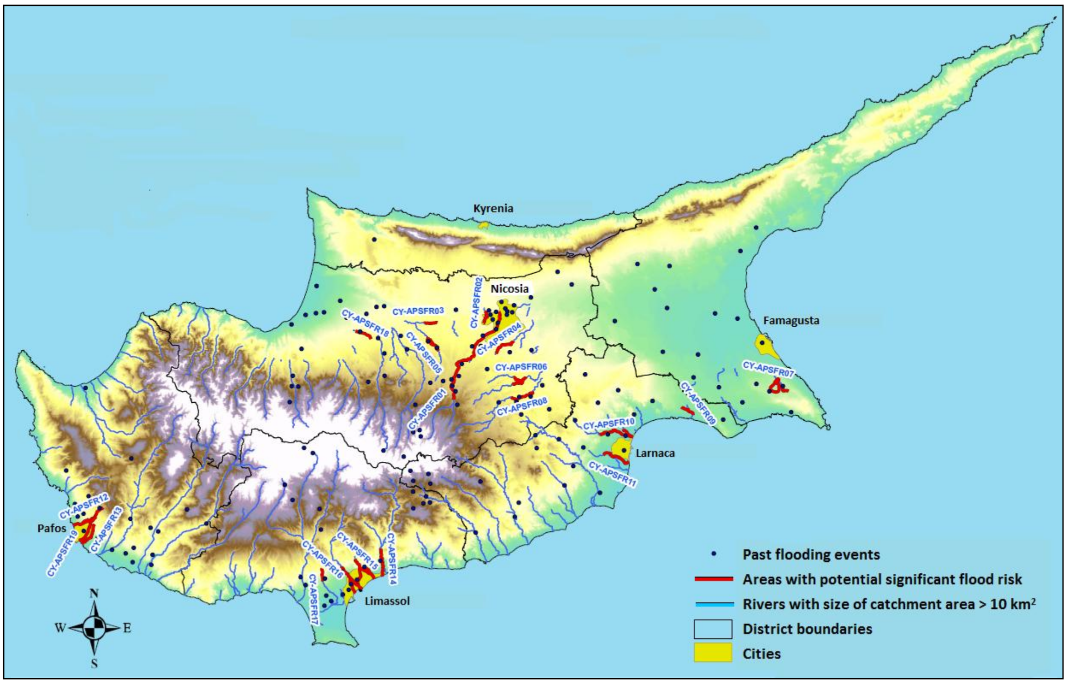

Figure 5-2: Areas with potential significant flood risk in Cyprus

Source: Water Development Department, 2012

Considering the above, the exposure of the coastal zones of Cyprus to storm flooding and inundation are characterized as **limited to moderate**.

5.4.1.2 Assessment of adaptive capacity

The resilience of coastal zones to storm flooding and inundation depends on the presence of sand dunes, trees and shrubs as well as of wetlands as they provide significant protection against storm waves, through their buffering properties and their ability to attenuate wave energy. Furthermore, the ability of ecosystems to retreat landwards where it is safer, enhances their adaptive capacity.

As far as human interventions for the protection from flooding and inundation in Cyprus are concerned, these are mainly in the form of hard engineering structures such as seawalls and coastal revetments. In addition, the measures applied in Cyprus for the protection from erosion, help prevent coastal flooding as well, by enhancing depositional processes along the coast. Structures such as groynes and breakwaters enhance the deposition of sediment on the beach thus helping to buffer against storm waves and surges, as the wave energy is spent on moving the sediments in the beach than on moving water inland (Short and Masselink, 1999). However, seawalls and revetments are not considered attractive for bathing beaches and thus breakwaters and groynes are the predominant defense works, although the latter are considered less drastic measures in case of a severe storm or flooding event.

After the Turkish invasion in 1974 there was an effort to restore the economy and tourist industry. Among the years 1974 and 1980 a number of hard defense structures were constructed along the Cyprus coast. The main type of works was hammer head groins which were constructed illegally by hotel owners in an attempt to create more attractive sandy beaches. In addition, a number of breakwaters were constructed by the government. In 1992, the Government decided to adopt a moratorium in the construction of the hard structures until the completion of the study ICZM for Cyprus. The study was completed in 1996 and until then no construction / development took place. In 1998, the required financial resources were obtained and the Cyprus Government started the implementation of these Master Plans. In 1998 the Cyprus government started with the implementation of these Master Plans. The Department of Public Works in cooperation with the National Technical University of Athens, also implemented a project (2000-2006), which was a continuation of the previous one that deals with three (3) new coastal areas in Paphos. The goal was to identify the proper methods to protect the coastline. The following years, Cyprus has prepared and implemented a number of additional Master Plans and intends to do the same for the rest of the coastal areas that is deemed necessary (Coccossis et al., 2008). The coastal defense works constructed in Cyprus during the period 1980-2011 are summarized in the following table.

Table 5-4: Coastal hard defense works

Site	Type of intervention	Year
Larnaca	10 breakwaters 6 breakwaters	1980-1990 2001
Zygi	5 breakwaters	2009-2011
Limassol	30 breakwaters 6 breakwaters 10 breakwaters	1980-1990 2001 2005-2007
Pafos	1 breakwater	1980-1990
Geroskipou	6 breakwaters	2010–2012
Poli Chrysochous	4 breakwaters	2009-2010
Kato Pyrgos	5 breakwaters	2010-2011
Maroni	3 groynes (illegal)	-
Vrisoudhia	1 groyne (illegal)	-
Kambourias	coastal road revetment	2008
Niolima	2 groynes (illegal)	-
Pentaschinos	2 groynes (illegal)	-
Yanoudhia	2 groynes (illegal)	-
Yanoudhia	coastal road revetment	2008
Platy	3 groynes (illegal)	-
Platy	coastal road revetment	2007
Alaminos	4 breakwaters	2000
Softades	2 groynes (illegal)	-

Site	Type of intervention	Year
Kokkinadhia	coastal road revetment	2004/08

Source: Montanari, 2010; DPW

Fishing shelters, which are constructed for the protection of fishing boats against extreme events such as storm and large waves, also protect the coast. Currently in Cyprus there are 11 fishing shelters in operation.

Artificial reefs which are actually submerged breakwaters also provide protection from flooding by absorbing part of the incident wave energy before it reaches the coast. The DMFR will create up to 4 artificial reefs in the marine areas of Famagusta, Limassol and Paphos (Source: Strategy for the creation of artificial reefs, Cyprus).

In addition, to prevent coastal squeezing and allow for landwards retreat, the Foreshore Protection Law of Cyprus prohibits building development except for light structures (sheds, footpaths, etc.) in the zone within 100 yards (91,44m) of the high water mark. The foreshore area in Cyprus is public property falling under the jurisdiction of this Law (Coccossis et al., 2008). However, the implementation of the Foreshore Protection Law is not adequately monitored, resulting in numerous violations and interventions in the foreshore zone.

Taking into account the abovementioned measures that are applied in Cyprus as well as their effectiveness, it is considered that the adaptive capacity of Cyprus' coastal zones to storm flooding and inundation is **limited to moderate**.

5.4.2 Coastal Erosion

5.4.2.1 Assessment of sensitivity and exposure

Sensitivity

The areas that are most sensitive to coastal erosion are the low-lying areas and the sandy and gravel beaches. As also mentioned before, less than 5% of Cyprus coastline is comprised of low-lying areas[18] with the main low-lying area being Larnaca (EC, 2009). Sandy beaches are predominant in the large bays of Cyprus as for example in Famagusta, Larnaca, Limassol, Polis Chrysochou and Morphou where the majority of tourism concentrates.

Considering the above, the sensitivity of Cyprus' coastal zones to erosion is characterized as **high**.

[18] Low-lying areas are defined as 10 km of coastal zone below 5 metres elevation

Exposure

For the assessment of the exposure of Cyprus' coastal zones to coastal erosion, data on the sea level rise and on the presence of coastal erosion in Cyprus will be used as indicators. Several climatic factors which could also be used as exposure indicators are the frequency and intensity of rainfall, storms and waves that the coastal zones of Cyprus are exposed. However, in absence of concrete data on the last indicators the assessment will be based on the first two indicators.

As also mentioned before, the sea level changes in Cyprus as observed during the period 1993 and 2000 show an increase of 5-10 mm/year. Taking into consideration the land lift up of 0-1 mm/year that Cyprus is experiencing, the exposure of Cyprus to sea lever rise is considered as moderate.

According to Coccosis et al. (2008), 110km or 30% of the coastline which is under the control of the Republic of Cyprus is subject to erosion. According to another older source (Research Promotion Foundation, 2006), the percentage of erosion in Cyprus reaches 37.8%, fact that places the country among the countries in the European Union with the highest rates of coastal erosion.

To this end, the exposure of the coastal zone against erosion is considered to be **high to very high**.

5.4.2.2 Assessment of adaptive capacity

The resilience of coastal zones to coastal erosion depends on the ability to recharge sediment supply mostly from rivers. However, as most rivers in Cyprus are dammed, the sediment supply to coasts from rivers is blocked.

As far as human interventions for the protection from coastal erosion in Cyprus are concerned, these are mainly hard coastal defense structures such as breakwaters and groynes for enhancing depositional processes along the coast. The coastal hard defense works constructed in Cyprus during the period 1980-2011 are summarized in Table 5-4.

Hard coastal structures have been considered for several decades the remedy for combating coastal erosion. The years proved that in the long run, hard interventions can have serious negative impacts both on coastal morphology and coastal environment. The sustainable development of the coastal areas asks for combining erosion control and good environmental practices, within the framework of Integrated Coastal Zone Management schemes. Coastal defense and protection structures are usually constructed as emergency measures, without taking into consideration environmental and social impacts. Generally, people and generally public opinion and decision makers support strongly the construction of hard coastal works, such as breakwaters, as the solution to coastal erosion problem and they do not accept easily demolition of structures (Loizidou and Loizides, 2007).

An important step in the direction for introducing integration in coastal protection actions was the Environmental Impact Law of 2001 (Law 57(I)/2001), through which it is necessary to proceed with an Environmental Impact Study before the construction of any coastal protection work (Loizidou and Loizides, 2007).

As far as the funding of these construction works is concerned, the Council of Ministers took a Ministerial Decision in 2000, arranging the funding cooperation among competent authorities concerning coastal structures. The Decision defines the following percentage of each authority's financial participation in the total cost for the construction of coastal structures (Loizidou and Loizides, 2007):

- If the structures are needed for coastal protection to counteract erosion, then the Government contributes the 50% and the Local Authority the rest 50%
- If erosion is not a serious problem and the structures are needed mainly to enable recreational uses of the coast, then the contribution of the Government goes down to 30% and the rest 60% is covered by the Local Authority. The 30% of the Local Authority's contribution can be covered by private funding, from the Hotel owners who are going to benefit from the structures.

Non Governmental Organizations (NGO's) in Cyprus focused on coastal zone protection (like CYMEPA and AKTI) organized several awareness raining campaigns for the public. Local Authorities hosted workshops and happenings. The effort was and is to give people and the Local Authorities the information on the alternative, environmental friendly coastal protection methods and promote the need for integration. The Environmental Service and Coastal Unit of the Ministry of Agriculture, Natural Resources and Environment of Cyprus support this effort (Loizidou and Loizides, 2007).

Regarding beach nourishment, this was firstly applied on a specific area in Limassol. The material was brought from the extension works in Limassol Port. The total amount of sand brought was 20.000 m^3. In addition, in a certain area of the Famagusta region a number of hotel owners used sand nourishment to improve the quality of the beach and create more friendly access to the beach (in rocky areas). In addition small pilot nourishment projects with sand were carried out in Larnaca and Pafos District. However, the responsible Municipality/Local Authority did not have the financial resources to continue the project and replace any sand losses undertaken during the year.

Finally, another measure that was undertaken towards the reduction of the pressures exerted on the coastal zones of Cyprus, coasing erosion is the prohibition of sand and gravel mining activities by law.

The adaptive capacity of the coastal zones in Cyprus to coastal erosion is characterized by high reversibility, as where proper coastal defense works have been implemented, satisfactory results have been observed and the problem of erosion has been restored. However, considering that the coastal zones continue to be subject to several pressures causing erosion that cannot be reduced for the time being and that coastal defense works have not been implemented to all areas with erosion problems, the adaptive capacity of coastal zone against erosion can be assessed as **moderate**.

5.4.3 Degradation of coastal ecosystems

5.4.3.1 Assessment of sensitivity and exposure

Sensitivity

Estuaries and coastal aquifers are sensitive to sea level rise due to the saltwater intrusion that will be induced especially in low-lying areas. The main estuaries of Cyprus (6 in total) are located mostly in the southern coasts of the island and are presented in the following figure.

Figure 5-3: Estuaries of Cyprus

A total of 15 out of the 19 groundwater bodies in Cyprus which are under government control, are coastal or part of them is located at the coast. As also mentioned before, less than 5% of Cyprus coastline is comprised of low-lying areas[19] with the main low-lying area being Larnaca (EC, 2009).

In addition, all coastal ecosystems are sensitive to sea level rise and extreme weather events (e.g. storms, floods, tidal waves) due their impacts on them, i.e. inundation, shrinkage -when there is no available area for retreating landwards-, reduction in sediment supply and biomass due to erosion and soil salinity due to the salinization of coastal aquifers and the irrigation with low quality (saline) water – except for saltlakes and saltcedars (trees and shrubs) that are adjusted to saline conditions. Finally, aquatic coastal ecosystems are sensitive to water temperatures increases.

As for the coastal ecosystems that are referring to wetlands, they are exposed to acidity changes and circulation patterns at coastal waters. For the case of Cyprus, it is expected that

[19] Low-lying areas are defined as 10 km of coastal zone below 5 metres elevation

the coastal circulation patterns will change because of changes in temperatures, wind speed and currents in the coastal zone (Harrould-Kolieb et al., 2009).

The coastal ecosystems in Cyprus of high biodiversity value that are sensitive to the climate change impacts are the Larnaca salt lake, the Akrotiri peninsula wetland, the Akamas peninsula and especially the Lara/Toxeftra Turtle Reserve, the Cape Greko marine caves and the Poli Chrysochous coastline (Parari, 2009). It is estimated that approximately 55 km or 19% of the Cyprus coastline (area under government control) comprises of such areas, which are also under protection status (see Table 5-1).

However, it must be mentioned that the sensitivity of these systems increases if taking into account the existing anthropogenic pressures that are subjected to.

Thus, the sensitivity of these ecosystems against degradation can be considered as **moderate to high**.

Exposure

In absence of data on the degradation of coastal ecosystems in Cyprus, a number of other indicators indirectly implying exposure to degradation will be used, such as the sea level rise, the salinization of coastal aquifers and the presence of coastal erosion in Cyprus.

As also mentioned before, the sea level changes in Cyprus as observed during the period 1993 and 2000 show an increase of 5-10 mm/year. Taking into consideration the land lift up of 0-1 mm/year that Cyprus is experiencing, the exposure of Cyprus to sea lever rise is considered as moderate.

According to Coccosis et al. (2008), 110km or 30% of the coastline which is under the control of the Republic of Cyprus is subject to erosion. According to another older source (Research Promotion Foundation, 2006), the percentage of erosion in Cyprus reaches 37.8%, fact that places the country among the countries in the European Union with the highest rates of coastal erosion.

As regards to aquifer salinization, 12 out of 19 groundwater bodies in Cyprus have been exposed to seawater intrusion while the coastal zones of several aquifers in Cyprus have been abandoned due to this phenomenon. In Figure 5-4, the aquifers of Cyprus exposed to salinization are presented.

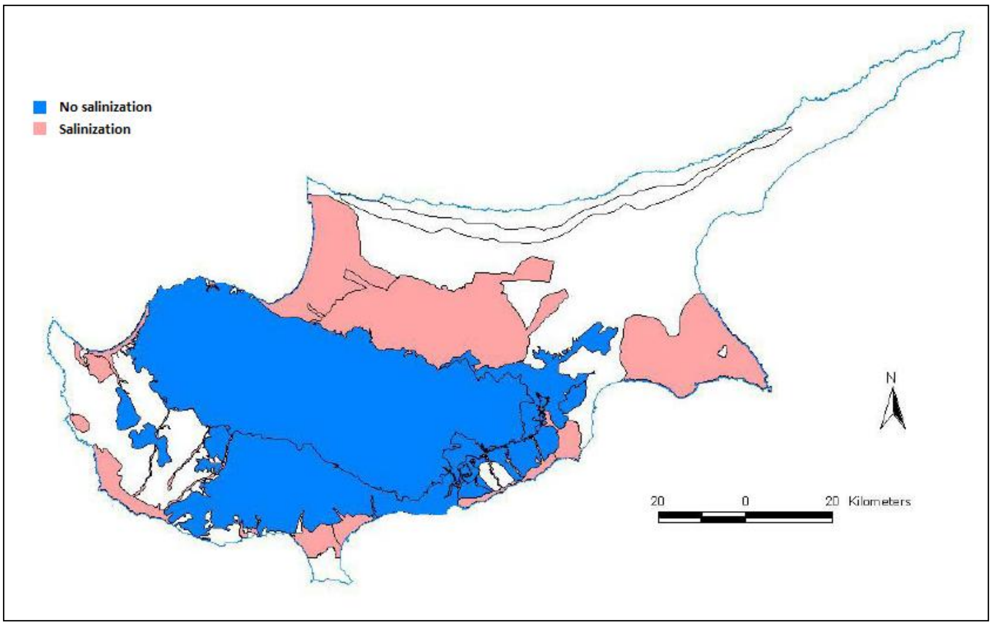

Figure 5-4: Salinization in the groundwater bodies of Cyprus

Source: Water Development Department, 2008

Given that there are no sufficient data for the assessment of exposure of coastal ecosystems in Cyprus to degradation, no characterization is given.

5.4.3.2 Assessment of adaptive capacity

The extent to which a coastal system is affected by sea-level rise will strongly depend on its resilience to changes. The survival of coastal wetlands is dependent upon sediment availability and/or local biomass production, as well as the potential for these ecosystems to migrate inland (Sterr et al., 2003). In addition, non-climate stresses may already have adversely affected the coastal system's resilience and thereby its ability to cope with additional pressures (Klein, 2002).

Coastal defense structures presented in Section 5.4.1 and Section 5.4.2 also contribute towards the protection of coastal ecosystems from flooding and erosion. As for the legal measures, in line with the EU Habitat Directive, Cyprus compiled a national list of habitats identified as 'special areas of conservation'. This list of important areas for Cyprus includes also lakes and wetlands nearby the coastline. By restricting mass-scale development in these areas, Cyprus wants to make a step towards the conservation of water-related eco-systems.

As there are no sufficient data on the exposure of coastal ecosystems to degradation, it cannot be assessed whether the adaptive capacity is satisfactory and hence, no characterization is given.

5.4.4 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of the coastal zones to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of coastal zones against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for coastal zones of Cyprus are summarized in Table 5-5.

Table 5-5: Overall vulnerability assessment of the coastal zones of Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Coastal storm flooding and inundation	Moderate (3)	Limited to Moderate (2)	Limited to Moderate (2)	Limited (0.5)
Coastal erosion	High (5)	High to Very high (6)	Moderate (3)	Moderate (2.5)
Degradation of coastal ecosystems	Moderate to High (4)	Not evaluated	Not evaluated	-

As a result, it is concluded that the current vulnerability of the coastal zones in Cyprus to climate changes focuses mainly on the coastal erosion, which already constitutes an issue for Cyprus' coasts and although it is addressed in a quite satisfactory degree, it is expected that climate changes will accelerate the phenomenon. The impact of coastal storm flooding and inundation is considered to present limited vulnerability for Cyprus' coasts taking into consideration the fact that this is not such an extensive issue for Cyprus for the time being, while the impact of the degradation of coastal ecosystems was not evaluated due to absence of sufficient information on the subject.

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6 BIODIVERSITY

Abbreviations and Acronyms

CAMP	Coastal Area Management Programme
CBD	Convention on Biological Diversity
CIESM	la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DMFR	Department of Fisheries and Marine Research
DoA	Department of Agriculture
DoE	Department of Environment
DoF	Department of Forests
EC	European Commission
EastMed	Scientific and Institutional Cooperation to Support Responsible Fisheries in the Eastern Mediterranean
EEA	European Environment Agency
ESSEA	Earth System Science Education Alliance
FAO	Food and Agriculture Organization
GSD	Geological Survey Department
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
MA	Millennium Ecosystem Assessment
MANRE	Ministry of Agriculture, Natural Resources and Environment, Republic of Cyprus
MAP	Mediterranean Action Plan
MedSeA	Mediterranean Sea Acidification in a Changing Climate
NGO	Non-Governmental Organization
NRE	Natural Resources and Environment
RAC/SPA	Regional Activity Centre for Specially Protected Areas
UN	United Nations
SCI	Sites of Community Importance
SPA	Special Protection Areas
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
UNCBD	United Nations Convention on Biological Diversity
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
WCMC	World Conservation Monitoring Centre
WDD	Water Development Department

WHO	World Health Organization

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6.1 Climate change and biodiversity

The United Nations Convention on Biological Diversity (UNCBD) defines biodiversity highlighting the importance of biodiversity: “the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems”.

Projected changes in climate, combined with land use change and the spread of exotic or alien species are likely to limit the capability of some species to migrate and therefore will accelerate species loss (CBD, 2007). Nevertheless, there is allready ample evidence that climate change affects biodiversity. According to the Millennium Ecosystem Assessment, climate change is likely to become one of the most significant drivers of biodiversity loss by the end of the century.

Examples of impacts on biodiversity due to climate change are phenomena such as “summit trap phenomenon” (species inhabiting mountain summits are forced to move to higher altitudes when temperatures increase), shifting distribution ranges of species and the habitats they compose, changing phenology, effects on plant physiology and changing community structure and species interactions (Delbaere, 2005).

Cyprus due to its geographical position in the eastern part of the Mediterranean Sea, bears all the characteristics of a semi-arid climate and some of the deficits of the global climate change. During the latest decades, remarkably low precipitation has been recorded most likely applying pressure in biodiversity.

6.2 Baseline situation

6.2.1 Status of biodiversity in Cyprus

Cyprus is located in the Mediterranean Basin, characterized as a biodiversity hotspot (Myers N. et al., 2000) (Figure 6-1), and is a part of the Mediterranean biogeographical region, (Figure 6-2). In addition, Cyprus is one of the world's major centres for plant diversity (Medail & Quezel, 1997), and has the world's second highest percentage of endemic plant species (Ornat & Correas, 2003).

The rich biodiversity of Cyprus is the result of the combination of the geographical structure, landscape isolation due to its insular character, surrounding sea, topographic relief, geological structure and of course climatic conditions. The flora and fauna of the island are adapted to the various natural biotopes and climatic conditions, resulting in a large number of endemic and rare species (DoE, 2000).

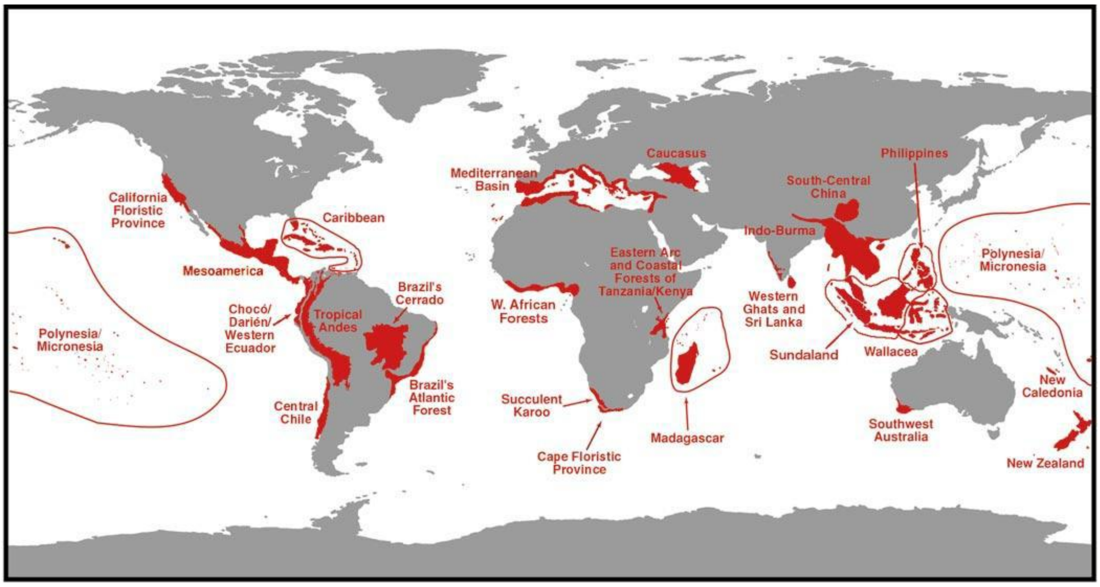


Figure 6-1: The 25 hotspots. The hotspot expanses comprise 30-3% of the red areas

Source: Biodiversity hotspots for conservation priorities (Myers et al., 2000)

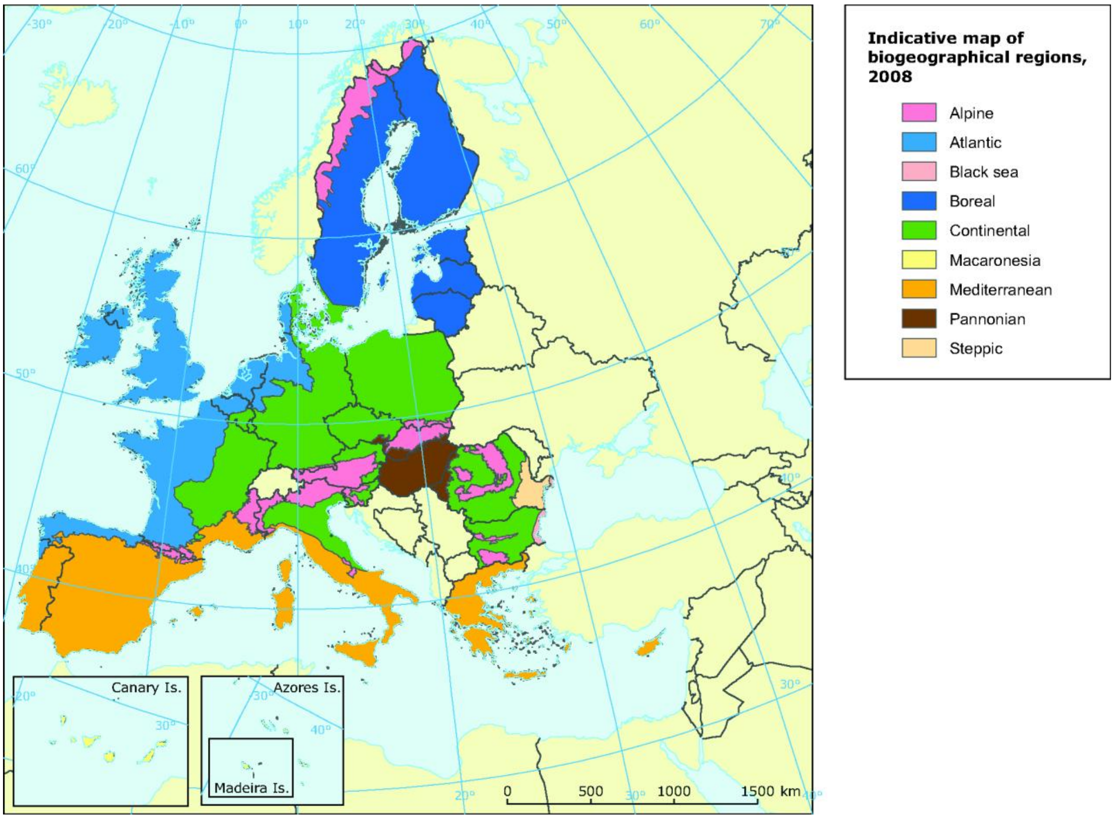


Figure 6-2: Indicative map of biogeographical regions, 2008

Source: Biogeographical regions in Europe (Directorate-General for Environment, 2009)

It is a practice to define biodiversity in terms of genes, species and ecosystems (Swingland, 2001; Dodson, et al., 1998). More specifically, according to the Global Biodiversity Strategy, biodiversity is the totality of genes, species and ecosystems in a region, and as a result can be divided into three hierarchical categories (genes, species, and ecosystems) that describe quite different aspects of living systems and that scientists measure in different ways (WRI, IUCN, UNEP, 1992). The genetic diversity is defined as the variation of genes within species, the species diversity as the variety of species within a region and the ecosystem diversity is harder to measure than previous two because the “boundaries” of communities-associations of species-and ecosystems are elusive (WRI, IUCN, UNEP, 1992). In order to present the diversity of nature in Cyprus, two of the terms which define biodiversity will be used: the **ecosystem diversity** and **the species diversity**.

6.2.1.1 Ecosystem diversity

The ecosystems in Cyprus include 48 habitat types, 14 of which are priority habitat types according to the Habitats Directive of the European Union (Council Directive 92/43/EEC, 1992) and 4 are endemic habitat types (*Serpentinophilous* grasslands of Cyprus 62B0*, Peat grasslands of Troodos 6460*, Scrub forest of *Quercus alnifolia* 9390* and *Cedrus brevifolia* forests 9590*) (DoE, 2000). The main ecosystem types (habitats) in Cyprus are listed in the following table (Table 6-1).

Table 6-1: The main Ecosystem types (Habitats) of Cyprus

Habitats	General characteristics of geomorphology	General characteristics of flora	General characteristics of fauna	Additional information
ROCKS & CAVES	Exposed rock, limestone scree and rocky slopes.		Nest of the biggest bird of prey (*Gyps fulvus*).	Reduced agriculture and farming activities cause the spread of shrubs (phrygana), resulting in the succession of varied types of flora.
Caves			Bats.	Caves have not yet been extensively surveyed.
Rocky shores	Hard limestone shores from Cape Pyla to Paralimni and from Cape Kormakiti to Cape Andreas.	Brown algae such as *Stypopodium, Padina* and *Cystoseira.*	Occurrence of *Vermetus reef* or shelf, an east Mediterranean Cowry (*Cypraea spurc)* which is now under threat from too much collection, limpets (*Patella coerulea* and *P. lusitanica*), winkles and top shells of different species (*Monodonta turbinata* and *M. articulata* are the most common) and many other species of gastropods and hermit crabs. Encrusting sea weeds (*Lithothamnion* and *Lithophylum* species) and other seaweeds with calcareous skeletons. Newcomer Stromb shell (*Strombus persicus = S. decorada),* a Red Sea immigrant which seems to be competing with the Mediterranean Cone Shell (*Conus mediterraneous*).	
WOODLANDS &SCRUB	Total cover area: 41.95% (386,630 ha) of the total land area. Forests occupy predominantly the mountain ranges and high elevation areas (most forested land is found on the Troodos and Paphos forest areas).	*Pinus brutia*: the dominant forest species today in altitudes of 1200m and 1400m on south facing slopes, covering an area of 100,000 hectares which equals to the 11% of the total land area. Brutia pinus at Akamas, Paphos, Troodos, Adelphi, Makheras, and Stavrovouni Forests and the Pitsilia, Akrotiri areas. *Pinus nigra*: a forest species covering 6000 hectares at the highest elevations of Troodos Forest (1200-1900m). These forests are the main habitats for 50 endemic plant taxa (over the 40% of Cyprus' endemics). *Cedrus brevifolia*: a forest species with highly restricted		Forest cover in Cyprus shows a trend of small and gradual increase for both state and private forests.

		distribution and particularly sensitive to habitat disturbance. These forests are found at the Cedar Valley on the western Troodos Range. Other forest species: *Quercus alnifolia* (endemic golden oak), *Quercus infectoria* (Cyprus oak), *Arbutus andrachne* (the strawberry tree), *Cupressus sempervirens* (the Mediterranean cypress), and *Juniperus phoenicea* (the Phoenician juniper) Wild and cultivated groves at lower altitudes: *Olea europaea* (wild olive), *Ceratonia siliqua* (carob).		
Maquis, Garigue and Phrygana	Garigue and maquis cover the entire altitudinal ranges of Cyprus.	Garigue: on dry eroded soils and/or moderately eroded soils. Sclerophyllous shrub (maquis): habitat usually occurs near the coast and the broader Troodos Range. In the maquis ecosystem type, about 43 endemic species are found (Tsintides & Takis, 1998).		
Cultivated & abandoned cultivated land		Small fields with traditional arable cropping, tree crops (e.g. citrus, olives, vineyards, etc) with rich biodiversity. The abandoned agricultural areas are covered with woodlands, abundant lichens, mosses and ferns) and invertebrate fauna.		Abandoned agricultural land in rural areas has increased dramatically over the last 20-30 years.
FRESHWATER				
Wetlands	Streambeds, salt lakes, marshes and smaller riparian areas near natural springs, dams and artificial lakes cover a small part of Cyprus.	Five endemic plants.		Two wetlands of Cyprus (Salt Lakes of Akrotiri and Larnaka Salt Lake) are listed under the Ramsar Convetion, as being habitats for hundreds of species of migratory birds including flamingos.
Rivers & streams	There are few main rivers and even fewer that constantly flow to the sea due to the construction of dams.	Rich variety of species which depends on the river flow.		
Dams		Bank side vegetation with some rare plant species.	Habitats for a variety of wildlife.	
Coastal ecosystems	Long and small beaches, open areas, cliffs, capes, harbors, sand dunes and accumulations of pebbles.	Low and sparse coastal vegetation. Five endemic plants.		The 14% of the coastline is protected.
Salt lakes	Distribution around the east and south	Vegetation of a few species which are resilient to the salt content	Wildfowl and waders are protected by the	

		coasts.	of the substrate.	Special Protection Areas under the EU Birds Directive.	
	Sand dunes	Coastal hills formed at the back of a beach by deposits of materials.	Rich vegetation. The 20% of the national flora -including many endemic, rare and protected elements- exists in a very small area of few km^2 of the south coast.	Species-rich habitats for invertebrates.	Coastal sand dunes are among the most vulnerable habitats of Cyprus.
	Sea cliffs	Distributed in a limited extent of the coastline.		Important environments for bird-of-prey colonies and seabird colonies.	
Marine environment		Waters around Cyprus are of higher salinity and temperature from the rest of the Mediterranean. As highly oligotrophic in nature, there is high species diversity and low biomass.	*Posidonia oceanic*: angiosperm endemic to the Mediterranean, forms extensive meadows along the coasts of Cyprus (5-40m depth (priority habitat according to the EU Habitat Directive (92/43/EEC). *Cymodocea nodosa*: in 3-10m depth. *Caulerpa prolifera* and *Halophyla stipulacea*: in deeper waters.	*Pinna nobilis*: thrives in deeper waters. Several endangered marine species are accommodated in the coastal area of Cyprus such as the monk seal *Monachus monachus*, the marine turtles *Chelonia mydas* and *Caretta caretta*, the Triton trumpet shell *Charonia tritonis*, the pen shell *Pinna nobilis* and many others.	The occurrence of endangered species and the presence of well-preserved important habitats along the coastal waters of Cyprus are evidence that the marine environment of Cyprus is still in a good state with minor environmental impacts.
	estuaries	There are not many river deltas in Cyprus, due to the construction of many dams.			
	reefs	Deep-water outcrops below 25m depth. Reefs are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone.		Coral knobs house, the tubes of peacock fans, colonies of white and red fan-worm, brilliant red slime-sponges, the orange *Axinella*, the finger sponges feathery, pink *Aeolid* sea slugs, red soldier fish and the black-eyed and red-bodied anthias are some of the creatures of the sea around Cyprus.	
	Sea caves	Some of them are completely underwater.	Wide variety of species and communities.		Limited information is available.

Source: Fourth National Report to the United Nations Convention on Biological Diversity (DoE, 2000)

The ecosystems of Cyprus include several plant and animal species that need to be protected from several threats. Cyprus has established the EU nature and biodiversity policy in order to preserve its plant and animal communities, as shown in the following table (Table 6-2).

Table 6-2: List of Natura 2000

Site Code	Site Name	Area (ha)	SCI / SPA
CY2000001	MAMMARI-DENEIA	108.34	SCI
CY2000002	ALYKOS POTAMOS-AGIOS SOZOMENOS	409.69	SCI
CY2000003	PERIOCHI MITSEROU	613.25	SCI
CY2000004	DASOS MACHAIRA	4,431.96	SCI
CY2000005	MADARI-PAPOUTSA	4,582.17	SCI
CY2000006	DASOS PAFOU	60,276.25	SPA
CY2000007	PERIOCHI PLATY	623.68	SCI
CY2000008	KOILADA KEDRON-KAMPOS	18,273.12	SCI
CY2000009	FOUNTOUKODASI PITSILIAS	127.38	SCI
CY2000010	KOILADA POTAMOU MAROULLENAS	72.28	SCI
CY2000011	POTAMOS PERISTERONAS	37.79	SCI
CY2000012	KOILADA KARGOTI	107.09	SCI
CY2000013	TZIONIA	4,657.03	SPA
CY2000014	PERIOCHI ATSA-AGIOU THEODOROU	2,907.38	SPA
CY2000015	VONOKORFES MADARIS-PAPOUTSAS	12,835.08	SPA
CY3000005	KAVO GKREKO	1,877.06	SCI & SPA
CY3000006	THALASSIA PERIOCHI NISIA	191.13	SCI
CY3000007	FRAGMA ACHNAS	179.00	SPA
CY3000008	LIMNI PARALIMNIOU	272.74	pSCI & SPA
CY3000009	PERIOCHI AGIAS THEKLAS - LIOPETRI	70.51	SPA
CY4000001	PERIOCHI POLIS-GIALIA	1,751.47	SCI
CY4000002	CHA-POTAMI	2,628.92	SCI
CY4000003	KOILADA DIARIZOU	1,359.19	SCI
CY4000004	VOUNI PANAGIAS	947.73	SCI & SPA
CY4000005	EPISKOPI MOROU NEROU	419.67	SCI
CY4000006	THALASSIA PERIOCHI MOULIA	200.17	SCI
CY4000007	XEROS POTAMOS	4,114.43	SCI & SPA
CY4000008	MAVROKOLYMPOS	282.75	SCI
CY4000009	PERIOCHI SKOULLI	100.23	SCI
CY4000010	CHERSONISOS AKAMA	17917	pSCI
CY4000011	PERIOCHI AGIATIS	510.92	SCI
CY4000012	PERIOCHI STAYROS TIS PSOKAS-KARKAVAS	5,059.36	SCI
CY4000013	FAROS KATO PAFOU	87.084	pSCI & SPA
CY4000014	PERIOCHI DRYMOU	7.93	SCI
CY4000015	PERIOCHI KRITOU MAROTTOU	4.93	SCI
CY4000016	FARAGGIA AGIAS AIKATERINIS-AGIAS PARASKEUIS	1,204.43	SPA
CY4000017	GKREMMOI CHANOUTARI	2,468.94	SPA
CY4000018	EKVOLES POTAMON EZOUSAS XEROU KAI DIARIZOU	825.78	SPA
CY4000019	ZONI EIDIKIS PROSTASIAS KOILADAS SARAMA	1,557.44	SPA

Site Code	Site Name	Area (ha)	SCI / SPA
CY4000020	ZONI EIDIKIS PROSTASIAS KOILADAS DIARIZOU	4,901.31	SPA
CY4000021	KOILADA EZOUSAS	4,720.44	SPA
CY4000022	KREMMOI EZOUSAS	1,571.31	SPA
CY4000023	ZONI EIDIKIS PROSTASIAS CHERSONISOS AKAMA	18081,97	SPA
CY5000001	DASOS LEMESOU	4,836.79	SCI
CY5000004	ETHNIKO DASIKO PARKO TROODOUS	9,016.72	SCI & SPA
CY5000005	AKROTIRIO ASPRO-PETRA ROMIOU	2,490.93	SCI & SPA
CY5000006	KOILADA LIMNATI	439.33	SCI
CY5000007	PERIOCHI ASGATAS	107.00	SCI
CY5000008	PERIOCHI KOILADAS XYLOURIKOU	3,205.98	SPA
CY5000009	POTAMOS PARAMALIOU	1,786.70	SPA
CY5000010	ZONI EIDIKIS PROSTASIAS CHA-POTAMI	7,990.60	SPA
CY6000002	ALYKES LARNAKAS	1,561.49	SCI & SPA
CY6000003	PERIOCHI LYMPION-AGIAS ANNAS	521.18	SCI
CY6000004	DASOS STAVROVOUNIOU	1,929.71	SCI
CY6000005	PERIOCHI LEFKARON	132.12	SCI
CY6000006	ETHNIKO DASIKO PARKO RIZOELIAS	90.60	SCI
CY6000007	POTAMOS PANAGIAS STAZOUSAS	1,746.46	SPA
CY6000008	POTAMOS PENTASCHINOS	4,058.53	SPA
CY6000009	PERIOCHI KOSIIS-PALLOUROKAMPOU	3,720.73	SPA
CY6000010	LIMNI OROKLINIS	56.47	SPA
CY6000011	LIMNI OROKLINIS	53.52	pSCI

** "p" is for the proposed areas*

Source: MOA

6.2.1.2 Species diversity

6.2.1.2.1 Flora

The flora of the island includes in total 1910 taxa (species, subspecies, varieties, forms and hybrids) as native or naturalized. The 143 of these taxa are endemic and more than 400 are cultivated (Unit of Environmental Studies). Overall, the percentage of Cyprus' endemism (calculating all the taxonomical levels) is 7.39%, which is one of the highest in Europe (Hadjichambis & Della, 2007). The recorded indigenous plant taxa in the area consist of 52 trees, 131 shrubs, 88 subshrubs and 1637 herbs (DoF, 2005; Endreny & Gokcekus, 2008).

Most of the endemic plants of Cyprus are located in the two mountain ranges of the island, as 94 endemic plants are developed in the mountain range of Troodos (only the National Forest Park Troodos hosts a total of 786 plant taxa) and 56 in the mountain range of Pentadaktylos (DoE, 2000). Another characteristic of the mountain areas of Cyprus is the tree nature-monuments (or Giant Trees), meaning trees or high shrubs with usually large dimension and age, which generally exceed two or three centuries (DoF). Mushrooms, bryophytes and lichens have not been adequately studied but there is evidence that numerous species exist. Furthermore, the sea around Cyprus is characterized by a diverse array of important habitats and hosts a considerable number of endangered species. Coastal vegetation is mostly low and sparse, and five endemic plants are found in this belt (DoE, 2000).

Due to the uniqueness of the nature of Cyprus, about 238 indigenous plant taxa have been classified as threatened during a recently implemented project by a group of government departments and NGOs, based on the IUCN Red List criteria (DoE, 2000). Additional measures have been taken in order to preserve certain plant communities, as shown in the following table (Table 6-3).

Table 6-3: List of the protected flora species of Cyprus

Flora species	Legal protection	In situ protection	Ex situ protection
Troodos rockcress *(Arabis kennedyae)*	Bern Convention (Appendix I), priority species in Annexes II and IV of the EC Habitats Directive.	Located in Troodos National Forest Park and Paphos State Forest, both of which are protected as SCI and SPA areas.	Seeds were collected from cultivated plants at the University of Athens in 1994 and stored in the Seed Bank of the Department of Botany at the University of Athens.
Lefkara milk-vetch *(Astragalus macrocarpus subsp. Lefkarensis)*	Bern Convention (Appendix I), priority species in Annexes II and IV of the EC Habitats Directive.	Three sites with populations of this taxon have been nominated as SCI by the European Natura 2000 Network.	A small number of seeds collected from the Lefkara and Asgata populations are stored in the seedbank of the Department of Botany at the University of Athens.
Akamas centaury *(Centaurea akamantis)*	Bern Convention (Appendix I), priority species in Annexes II and IV of the EC Habitats Directive.	The area where it is located is protected by a plan of the Forestry Department and designed as SCI area by the European Natura 2000.	Small numbers of seeds have been collected from the Avakas Gorge and stored in the seedbank at the Department of Botany at the University of Athens. The species has been successfully cultivated at the Cyprus Agricultural Research Institute.
Erysimum kykkoticum	The species is located in the protected area of the Paphos State Forest.	The Paphos State Forest, the area where the species is located, is designed as SCI and SPA area by the European Natura 2000.	
Kythrean sage *(Salvia veneris)*	Bern Convention (Appendix I), priority species in Annexes II and IV of the EC Habitats Directive. Part of the area, where the species grows, is the “Lakkovounara State Forest” which is protected by the Forest Law.		
Alyssum akamasicum	Bern Convention (Annex I)		
Brassica hilarionis Post	Bern Convention (Annex I)		
Centaurea akamantis	Bern Convention (Annex I)		
Chinodoxa lochiae	Bern Convention (Annex I)		
Crocus cyprius Boiss.	Bern Convention (Annex I)		
Crocus harmannianus	Bern Convention (Annex I)		
Delphinium caseyi	Bern Convention (Annex I)		
Onosma troodi kotschy	Bern Convention (Annex I)		
Ophrys kotschyi	Bern Convention (Annex I)		
Orchis Punctulata	Bern Convention (Annex I)		
Origanum cordifolium	Bern Convention (Annex I)		
Phlomis cypria	Bern Convention (Annex I)		
Pinguicula crystallina	Bern Convention (Annex I)		
Posidonia oceanica	Bern Convention (Annex I)		
Ranunculus kykkoensis	Bern Convention (Annex I)		
Sideritis cypria Post	Bern Convention (Annex I)		
Tulipa cypria	Bern Convention (Annex I)		

Source: “The top 50 plants of the Mediterranean islands” (de Montmollin & Strahm, 2005) and “The Red Data Book of the Flora of Cyprus” (Tsintides et al., 2007)

6.2.1.2.2 Fauna

Cyprus is considered as a biodiversity "hotspot" area (Myers et al., 2000), because it is the only centre of birds endemism in Europe and the Middle East (Bibby et al., 1992; Kourtellarides, 1998), a centre of insects endemism (Makris, 2003), a centre of plant diversity (WCMC, 1992; Pantelas et al., 1993; Hadjikyriakou, 1997; Tsintides et al., 2002; Tsindides & Kourtellarides, 1995) and a centre of mammals endemism (with six out of its 11 wild mammals being endemic) (Hadjisterkotis & Masala, 1995; Hadjisterkotis, 1996; Hadjisterkotis, 2003a; Bonhomme et al., 2004; Cucchi et al., 2006; Unit of Environmental Studies).

At present, there are about 32 mammal species (DoE, 2000), 24 reptile species (DoE, 2000), 3 turtle species -2 of which are marine (DoF), 3 amphibian species (frog species), 385 bird species (53 of which are permanent residents) (DoE, 2000), 250 fish species and approximately 6000 insects species (including 52 butterfly species) recorded in the island (DoF, 2012). The rich faunal species diversity and the many endemic species are the main reasons for the numerous measures for the protection of the island's biodiversity, as shown in the following table (Table 6-4).

Table 6-4: Faunal species diversity and the protected species

Fauna	Species Diversity	Protected faunal species and measures			
Mammals	32 species (of which 21 types of bats and 4 species of marine mammals).	9 species are included in the Annex of II Directive 92/43 and in particular 1 as priority (the Mediterranean seal *Monachus monachus*, that used to be abundant in the sea of Cyprus, has today been reduced to only few pairs). 2 mammals are included in the Annex I of the Habitat Directive (i.e. the Cyprus muflon (*Ovis orientalis ophion*) and *Rousettus aegyptiacus*).	Mammals	Monachus monachus – CR*	Annex II of SPA protocol, Annex II of Bern Convention
				Ovis orientalis ophion (Cyprus muflon) – VU*	Protected under Annex II and IV of Habitats Directive 92/43/EEC
				Rhinolophus Euryale – VU*	Protected under Annex II of Habitats Directive 92/43/EEC
				Capra aegagrus (Cyprus goat) – VU*	Protected under Annex II and IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
				Rousettus aegyptiacus	Protected under Annex II and IV of Habitats Directive 92/43/EEC
				Delphinus delphis – EN*	Annex II of SPA protocol, Annex II of Bern Convention
				Stenella coeruleoalba	Annex II of SPA protocol, Annex II of Bern Convention
				Tursiops truncatus	Annex II of SPA protocol, Annex II of Habitats Directive 92/43/EEC, Annex II of Bern Convention
				Carcharodon carcharias - VU*	Annex II of SPA protocol, Annex II of Bern Convention
Birds	More than 385 species (52 of them are permanent residents, while the rest are migratory). The number of visitors (and mainly the wintery) varies from year to year and depends on the climatic conditions in Northern and Eastern Europe, but also the rainfall on the island.		Birds	Numenius tenuirostris	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Pelecanus crispus – VU*	Protected under Annex II of SPA protocol
				Oxyura leucocephala – EN*	Protected under Annex II of Bern Convention
				Branta ruficollis – VU*	Protected under Annex II of Bern Convention
				Crex crex – LR*	Protected under Annex II of Bern Convention
				Emberiza aureola	Protected under Annex II of Bern Convention
				Gallinago media	Protected under Annex II of Bern Convention
				Larus audouinii – LR*	Protected under Annex II of Bern Convention
				Emberiza cineracea	Protected under Annex II of Bern Convention
Reptiles	24 species of reptiles and 3 species of amphibians. 4 endemic subspecies of lizards (endemic species of lizard *Phoenicolacerta troodica* found in	The snake species *Coluber cypriensis* was added in Annexes II and IV of Directive 92/43/EEC, as priority species. It has been characterized as endangered (EN) by IUCN.	Reptiles	Chelonia mydas – CR*	Protected under Annex II of SPA protocol, Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
				Caretta caretta – EN*	Protected under Annex II of SPA protocol, Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
				Natrix natrix cypriaca	Protected as freshwater fauna under the Fisheries Regulations (Reg. 273/90)

Fauna	Species Diversity	Protected faunal species and measures			
	the mountain of Troodos. 2 endemic species of snake as well as 2 endemic subspecies (the Cypriot snake *Coluber cypriensis* and the grass snake *Natrix natrix cypriaca* are both endemic species of reptiles in Cyprus). Marine turtles.	2 marine turtles (the green turtle *Chelonia mydas* and the loggerhead *Caretta caretta*), which visit the sandy beaches of Cyprus in order to lay their eggs, are priority species of Directive 92/43/EEC.		Mauremys caspica	Protected under Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
				Coluber cypriensis – EN*	Protected under Annex II and IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
				Emys orbicularis	Annex II of Bern Convention
				10 other species	Protected under Annex II of Habitats Directive 92/43/EEC
			Amphibians	Bufo viridis	Protected under Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention, Fisheries Regulations (Reg. 273/90)
				Hyla savignyi	Protected as freshwater fauna under the Fisheries Regulations (Reg. 273/90)
Invertebrates			Arthropods	Ocypode cursor	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Potamon potamios	Specifically protected under national legislation
				Artemia salina	Specifically protected under national legislation
			Molluscs	Charonia tritonis	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Erosaria spurca (Cypraea spurca)	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Luria lurida	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Tonna galea	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Lithophaga lithophaga	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Pholas dactylus	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Pinna nobilis	Protected under Annex II of SPA protocol, Annex IV of Habitats Directive 92/43/EEC
			Echinoderms	Asterina panceri	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Ophidiaster ophidianus	Protected under Annex II of SPA protocol, Annex II of Bern Convention

Fauna	Species Diversity	Protected faunal species and measures			
				Centrostephanus longispinus	Protected under Annex II of SPA protocol, Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
			Porifera	Axinella polypoides	Protected under Annex II of SPA protocol
				Axinella cannabina	Protected under Annex II of SPA protocol
				Geodia cydonium	Protected under Annex II of SPA protocol
Fish	The internal waters of Cyprus are exceptionally poor in indigenous fish, with the exception of the eels (*Anguilla anguilla*).		Fish	Aphanius fasciatus	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Hippocampus hippocampus	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Hippocampus ramulosus	Protected under Annex II of SPA protocol, Annex II of Bern Convention
				Mobula mobular – VU*	Protected under Annex II of SPA protocol, Annex II of Bern Convention

Source: Fourth National Report to the United Nations Convention on Biological Diversity (DoE, 2000); List of protected fauna species found in Cyprus (Hadjichristophorou, 2000); Revised National Strategy for Sustainable Development (DoE, 2010(a); USAID, 2006)

*IUCN categorization: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Low Risk (LR)

6.2.2 Pressures

Biodiversity is affected by numerous factors concerning the climate, ecology, society, culture, economy and technology. These features are necessary to be mentioned in order to present the current situation in Cyprus. A list of factors retrieved from a relevant study of the United Nations University (2005) and adjusted for the case of Cyprus, is presented in the following table (Table 6-5):

Table 6-5 : List of factors affecting biodiversity

Categories	Factors
Climate aspects	Variability (uneven geographic distribution and temporality of precipitation)
	Reduction of frequency of precipitation
	Increase of frequency of rainfall's intensity
	Increase of temperature (and certain variables of temperature)
	Heat-wave
	Reduction of snow cover in Troodos
	Increase of evapotranspiration (contributes to the intensification of soil drying)
	Other climate aspects
Ecological aspects	Temperature limitations
	Water variability (drought and heavy rains)
	Unfavorable climate (incl. variability)
	Geological instability (e.g. periodic seismic activity, geological erosion and sediment loads)
	Topographic difficulties (steepness, roughness)
	Restricted soil fertility and susceptibility
	Vulnerability of land resources
	Climate change
	Plant and animal diseases
	Natural hazard deposition
	Environmental pollution (e.g. waste and construction, pollution form quarrying)
	Deforestation
	Other ecological aspects
Socio-cultural aspects	Outmigration, manpower availability
	Missing of undapted land use regulations
	Land ownership and privatization
	Tradition and culture
	Education and knowledge on resource use
	Attitude and awareness towards land resources
	Abandonment of the rural areas and overexploitation of the left agricultural areas

Categories	Factors
	Overgrazing
	Geopolitical pressures between countries (more water drillings in the southern part of Cyprus after 1974)
	Other socio-cultural aspects
Economic aspects	Limited economic performance of agriculture
	Restricted market access, economic isolation
	Energy dependence on oil inputs
	Other economic aspects
Technological aspects	Lack of land use alternatives and arable land
	Poor land use (e.g. urban sprawl, commercial development, vehicle off-roading)
	Absence of crop rotation and fallow periods
	Overuse of fertilizers
	Too many water drillings and near the seashore
	High land use intensity (e.g. overgrazing, poor pasture management, poorly regulated hunting, poor tourism development in coastal and mountain areas)
	Unadapted irrigation practices (e.g. poor soil and water management for irrigated and rainfed crop production)
	Other technological aspects

The above mentioned pressures (Table 6-5) in combination with the factors of climate change deteriorate some environmental phenomena or create new more complicated conditions for the biodiversity of Cyprus. The major pressures on the biodiversity of Cyprus as a result of several activities are listed below:

- Stress in the coastline environment due to tourism development (changes of land use).
- Abandonment of primary agricultural areas due to urbanization.
- Reduction in quantity and range of invertebrate and seed food due to intense agricultural practises.
- Impacts on the biodiversity of small mammals due to intense agricultural practises (Unit of Environmental Studies).
- Eutrophication due to contaminated waters.
- Contamination of freshwaters from livestock waste (I.A.CO Ltd, 2007).
- Degradation of soil productivity due to desertification (I.A.CO Ltd, 2007)
- Overexploitation of fisheries stocks (DoE, 2000).
- Changes in plant species distribution due to the localised overgrazing (DoE, 2000).
- Threat of certain animal populations due to illegal hunting (DoE, 2000).
- Changes in plant species distribution due overexploitation and contamination of surface and ground water (DoE, 2000).
- Changes in forest plant species distribution in the abandoned parts of the unprotected state forests.

- The dam construction in Cyprus provided new habitats for the local animal population and for the migratory waterfowl. However, the local society in order to provide the additional opportunity of sport fishing introduced big populations of 16 species of exotic freshwater fish and the crayfish Procambarus clarkii in every dam. In 1995 only, the species of Mirror Carp (Cyprinus carpio), mosquito fish (Gambusia affinis) and Rainbow trout (Oncorhynchus myskiss) were introduced for fishing in the dams, but by 2000 largemouth bass (Micropterus salmoides) and crayfish (Procambarus clarkii) were added and later the Roach (Rutilus rutilus). Except roach all these species are known to be fed on either stage with amphibians (frogs, tadpoles and spawn). This combination of fish and crayfish eliminated the frog population from each dam and inevitably led the grass snake Natrix natrix cypriaca into extinction (Unit of Environmental Studies).

The above factors are used additionally, in order to assess the vulnerability of biodiversity due to climatic changes in a more integrated perspective.

6.3 Impact assessment

According to the Millennium Ecosystem Assessment (MA, 2005), impacts on biodiversity due to climate change have had a very rapid increase[xx] over the last century, especially in dry lands, mountains and polar regions (Figure 6-3).

Figure 6-3: Global impacts and trends

Source: Ecosystems and Human well-being Biodiversity Synthesis (MA, 2005)

The climatic factors that may have an impact on the biodiversity of Cyprus include the decreased rainfall and increased temperature, droughts, fluctuations in intense precipitation events, sea level rise, increased atmospheric CO_2 and changes in fire regimes. The general correlations between the observed climate changes in Cyprus and the impacts on biodiversity on terrestrial and aquatic ecosystems of temperate climates are listed in the following table (Table 6-6).

[xx] The ranking of climate change by the Millennium Ecosystem Assessment (MA, 2005) is based on evidence that climate change has already been affecting biodiversity (Secretariat of the Convention on Biological Diversity, 2007).

Table 6-6 : Relationship between observed climate changes and impacts on biodiversity

Observed climate change in Cyprus	Impacts on biodiversity in temperate climates			
	Terrestrial ecosystems		Aquatic ecosystems	
	Flora	Fauna	Flora	Fauna
Decreased rainfall & increased temperature	Decrease of soil moisture and thickness of soil layer affecting the associated plant species. (MOA)	Changes in food availability which are responsible for the changes in the distribution of animal species. (MOA)	Changes in ocean currents, in the temperature of the upper sea layers, in salinity and in the global thermoline are responsible for the changes in the distribution of plant species (UNEP, MAP, RAC/SPA, 2010).	The changes in sea currents routes can be correlated with effects on fish recruitment, mainly for the Lessepsians species. Also, alterations in sea currents routes are leading to changes in abundance of juvenile fish and therefore can be correlated with production in marine and fresh water. The fluctuations in sea water temperatures are responsible for changes in physiology and sex ratios of fished species, alteration in timing of spawning, migrations, and/or peak abundance and also, for the increasing of invasive species, diseases and algal blooms. These impacts are leading to reduced production of target species in marine and fresh water systems. Changes in the marine food-webs cause alterations to the food availability of fish, birds and marine mammals. Potential mismatch between prey (plankton) and predator (fished species) (Allison, et al., 2009).
Droughts	Soil droughts cause localized catastrophes of plants, extinction of plant species,	Soil droughts cause changes in habitats and food availability, affecting the	Changes in lake water levels and water flows in rivers and consequently to the bank side	Changes in lake water levels and water flows in rivers and consequently to the associated fauna species.

Observed climate change in Cyprus	Impacts on biodiversity in temperate climates			
	reduction of wild plants' resilience and alterations in the distribution of plant species (MOA).	associated animal populations (MOA).	vegetation.	
Heavy and/or intense precipitation events	Increased soil slippage events, which are responsible for localized catastrophes of plant species. Floods are responsible for localized catastrophes of plant species. Water logging of soils is responsible for the reduction of soil productivity. (MOA).	Landslides are responsible for the loss of animal populations (MOA). Floods are responsible for the drowning of animals (MOA).	Changes in timing and latitude of upwelling, in stratification and in mixing of nutrients in lakes and marine upwellings. (EEA, JRC, WHO, 2008)	Changes in pelagic distribution and productivity (EEA, JRC, WHO, 2008).
Sea level rise	A potential sea level rise or coastal floods are responsible for the salinization of coastal soils, hence the changes in soil pH and inevitably the changes in vegetation (EEA, JRC, WHO, 2008).	A potential sea level rise or coastal floods are responsible for the flooding of the coastline, salinization of coastal soils and changes in vegetation. These parameters are critical for the survival of the animals of the coastline (EEA, JRC, WHO, 2008).	The increased superlittoral and supralittoral inundation and the general changes in the structure of marine ecosystems can affect the spatial distribution of plant species, whose tolerance limit is depended on the maximum depth limit (e.g. *Posidonia oceanica* has a maximum depth tolerance limit of 42 meters in Cyprus, *Cymodocea nodosa* predominates in shallower waters of 2-10 meters, *Cystoseira*	Sea level rise can cause flooding, coastal erosion and the loss of flat and low-lying coastal regions. It increased the likelihood of storm surges, enforces landward intrusion of salt water and endangers coastal ecosystems and wetlands (EEA, JRC, WHO, 2008).

Observed climate change in Cyprus	Impacts on biodiversity in temperate climates			
			spp. habitats are found in shallow waters until 37m, *while Caulerpa prolifera* and *Halophyla stipulacea* are found in deeper waters (Hadjichristophorou, 2000; Parari, 2009).	
Increased atmospheric CO2	An enriched CO_2 atmosphere is responsible for the increased water use efficiency of some plants and as a result the altered competitive interactions of species (EEA, JRC, WHO, 2008).	Changes in food availability are responsible for the changes in the distribution of animal species (EEA, JRC, WHO, 2008).	Ocean acidification and changes in sea water pH lead to the saturation state of of calcium carbonate ($CaCO_3$) minerals affecting the distribution of plant species (MedSeA, 2011).	The combined effect of the Mediterranean seawater acidification -absorbing anthropogenic CO_2 per unit area- with the low tropospheric warming on the Mediterranean biogeochemistry and ecosystems, and the ecosystem services they support, through the direct impacts on its highly adapted calcareous and non-calcareous organisms, may be larger in the Mediterranean than in other European regions (MedSeA, 2011).
Changes in fire regimes (increased number of wildfires)	Localised catastrophes of plant species (DoF, 2005).	The challenge of forest fires leads to the expansion of grasslands and as a result to extinctions of forest animal species (DoF, 2005).		

For the purpose of this assessment, the impacts of climate change presented in Table 6-6 are grouped in the following impact categories (Table 4-4) and assessed in the sections that follow.

Table 6-7: List of the selected impacts for evaluation

Selected impacts for evaluation	
Terrestrial ecosystems	Distribution of plant species in terrestrial ecosystems
	Plant phenology of terrestrial ecosystems
	Distribution of animal species in terrestrial ecosystems
	Animal phenology of terrestrial ecosystems
Aquatic ecosystems	Marine biodiversity
	Freshwater biodiversity
	Phenology of aquatic ecosystems

Source: EEA, JRC, WHO, 2008

6.3.1 Impacts on terrestrial ecosystems

6.3.1.1 Distribution of plant species in terrestrial ecosystems

Climate change, with the milder winters, has affected the number of species, services of plants and plant communities. So far northward and uphill movements of plants and extinctions of species have been observed due to landscape fragmentations, emerging the concern about the resilience of wild plants to the rate of climate change. Another impact is the introduction of alien species[21], having caused ecological changes throughout the world in the past few hundred years (Clout & Lowie, 1997; Unit of Environmental Studies), such as diseases of local species and alterations of keystone species[22]. The invasive alien species

[21]An additional reason, recorded in Cyprus, is the human transportation of alien species across biogeographical boundaries.
[22] Keystone species are the species with the greater abundance in an area.

alter or even extinct populations and processes of the native species in the natural ecosystems.

In Cyprus: The general characteristics of the plant distribution in Cyprus are the low species richness, the sensitive endemic plant species and the several invasive plant species. Cyprus, due to its semi arid climate, suffers from droughts further affecting its species richness. In addition, the isolation due to its insular character in combination with its geomorphologic features, are the reasons for the many endemic and unique species of the island. Last but not least, the several recorded invasive plant species can be considered as an additional threat for the host plant species.

6.3.1.2 Plant phenology of terrestrial ecosystems

In temperate regions, with warm summers and cold winters, the length of growing season depends mostly on temperature. In places such as Europe, growing seasons last as long as eight months. Indicators for the length of growing seasons are the distance from the Equator (the further away a place is from the Equator, the shorter the growing season) and the height above sea level (higher elevations usually have colder temperatures).

There are two ways to determine the growing season in temperate regions. The first, and more usual, is the calculation of the average number of days between the last frost in spring and the first severe frost in autumn. The second, depending on crops, is the calculation of the average number of days that the temperature rises high enough for a particular crop to sprout and grow. Climate change affects the cold weather events which determine the growing season length, such as the radiation frost in small geographic regions and the advection frost for large geographic regions (Wake, 2005). As a result, changes have been noticed in plant phenology (Menzel, et al., 2006) hence in ecosystem functioning too. More specifically, changes such as the timing of seasonal events (budburst, flowering, dormancy, migration and hibernation) are included in the term of phenology (EEA, JRC, WHO, 2008).

In Europe, there is clear evidence of changing phenology the latest decades (Parmesan & Yohe, 2003; Root et al., 2003; Menzel et al., 2006). Changes in plant phenological phenomena due to climate change have been observed, such as a percentage of 78% of leaf unfolding, advancing trends for flowering and fruiting and only a 3% of a significant delay. Furthermore, an average advance of spring and summer has been observed and estimated to be 2.5 days per decade for the time period 1971-2000 (Menzel et al., 2006). This evidence reveals the markedly changes of spring's procedures over autumn's, which is actually the main responsible for the phenomenon of additional life cycles of species in a year (EEA, JRC, WHO, 2008).

In addition, there are observations such as the increased concentration of pollen in the atmosphere and its earlier start (on average 10 days earlier than 50 years ago), due to the changes of flowering (Nordic Council, 2005). These trends in seasonal events are generally believed that most certainly will continue to advance as temperature rises in the following decades (EEA, JRC, WHO, 2008).

Some effects of the phenological changes include changes in the wildlife, timing of procedures of farming (such as tilling, sowing, harvesting and earlier ripening of fruits), forestry and gardening (e.g. more frequent and longer periods of cutting grass) (EEA, JRC, WHO, 2008).

In Cyprus: Changes in phenological responses of plants have been noticed in several places of Europe, but there is no data available for Cyprus. The only relevant information about Cyprus is its participation in the survey "Growing Season Temperatures in Europe and Climate Forcings over the Past 1400 Years" (Guiot, Corona & ESCARSEL members, 2010). More specifically, proxy series of tree ring series of Cyprus were used in the survey, which revealed that the climate change we are currently living has not been seen in Europe for the past 1400 years (Table 4-4).

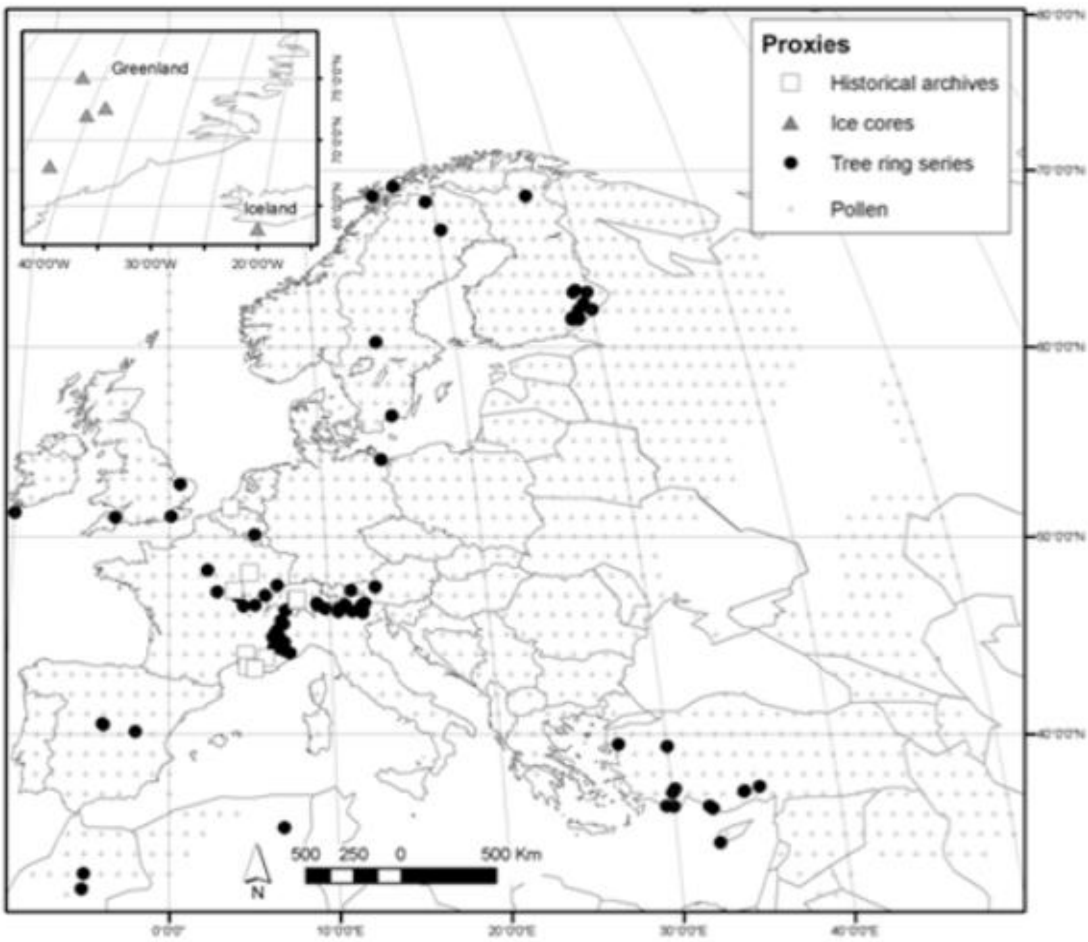


Figure 6-4: Map of the proxies used for the survey of "Growing Season Temperatures in Europe and Climate Forcings Over the Past 1400 Years"

Source: Growing Season Temperatures in Europe and Climate Forcings Over the Past 1400 Years (Guiot, Corona, & ESCARSEL members, 2010).

In order to extract safe conclusions regarding the impact of climate changes on plant phenology, the following are considered necessary:

- Determination of the growing season and timing of seasonal events (e.g. leaf unfolding, fruiting, budburst, flowering, dormancy, migration and hibernation) in the area
- Determination of plants' life cycles
- Data availability on plant phenological response to climate change from a long monitoring period
- Correlation with climatic conditions and clear distinction of the effect from human activities

6.3.1.3 Distribution of animal species in terrestrial ecosystems

The rate of climate change in combination with land fragmentations or change of land use are supposed, nowadays, to be the main reasons for the northward and uphill movement of several animal species and the decline of species richness and composition. More specifically, temperature rise affects the habitat and food availability of animal species. As a result, populations migrate in order to find shelter. The changes in geographical distributions of animal populations bring new species in contact. Therefore, changes in communities appear due to the intrusion of new competitors. In general, the keystone species expand their distribution over the less adaptable. The invasive species bring along new threats for the host populations such as diseases. The most typical example is the establishment of new pest species -such as migratory moths, butterflies, ticks and mosquitoes- due to warmer winters.

Generally for the European area, there are estimations about animal northeast movement of 550km, 20% population shrinkage for the breeding birds by the end of the century, and serious threat for reptiles and amphibians (Hickling et al., 2006; Araújo et al., 2006) due to their limited dispersal ability (EEA, JRC, WHO, 2008). Furthermore, projections about the mammals of the Mediterranean regions suggest up to 9% risk of extinction (assuming no migration) during the 21st century (Andreou et al.).

<u>In Cyprus</u>: The most threatened species -in terms of population and species- are located in terrestrial environments as shown in Figure 6-11. The main reasons for the increased sensitivity to climate change are the changes in food availability and landscape fragmentations.

It's worth mentioning that the recorded animal intrusions (mammals) in the island are the result of human intervention. According to Hadjisterkotis (2000a) and Hadjisterkotis & Heise-Pavlov (2006), five wild boars (*Sus scrofa*) were introduced to the island for game farming. Several years after the introduction of the animal, in 1994, the wild boar was illegally released in the Limassol Forest and in 1996 in the Troodos National Forest Park. In 1997, the government decided its eradication from the area (Hadjikyriakou and Hadjisterkotis, 2006). The main reasons for that decision were the prevention of a possible environmental destruction of the National Forest of Troodos (an area of high biodiversity in Cyprus, where 72 endemic plant species are located) and the danger of transmitting diseases to livestock. In January 2005, there were no wild boars seen in Troodos, Paphos and Limassol forests.

Apart from the wild boar, the introduction of pheasants for hunting in habitats of the indigenous black francolin by the Game Service of Cyprus caused many problems due to the similar habitat requirements of both animals (Unit of Environmental Studies).

6.3.1.4 Animal phenology of terrestrial ecosystems

Climate change has affected life cycles of many species. In general, temperature rise is the main responsible for the changes in the metabolic limits of animals and the reduction of the thermoregulation capacity of warm blooded animal species. Another reason for the changes of the animal phenology is the milder springs, which are responsible for the length of breeding seasons and as a result for the reproduction of more generations of temperature-sensitive insects. Their future though is uncertain, depending on the climate conditions and the available food for the young (Reading, 2007; EEA, JRC, WHO, 2008). In addition, the milder winters allow the survival of insects making their growth easier. These trends are generally projected to continue, if climate warming increases in the future (EEA, JRC, WHO, 2008).

In Cyprus: In general, there is no information available about the animal phenology for Cyprus, apart from the noticed increased populations of insects in the forests of Cyprus (DoF).

In order to extract safe conclusions regarding the impact of climate changes on animal phenology, the following are considered necessary:

- Determination of the length of growing season and breeding seasons in the area
- Data availability on animal phenological response to climate change (e.g. metabolic limits of animals and thermoregulation capacity of warm blooded species) from a long monitoring period
- Correlation with climatic conditions and clear distinction of the effect from human activities

6.3.2 Impacts on aquatic ecosystems

6.3.2.1 Marine biodiversity

The location of the island of Cyprus between three different continents in a marine territory and its proximity to natural and manmade nautical channels which favor species migration and relocation, and its variety of indigenous species have turned Cyprus into a biodiversity hotspot. The marine flora and fauna of Cyprus are characterized by great diversity and low biomass, making them vulnerable to climate change. Changes in temperature, salinity and nutrient levels can be the starting point of any of the three courses induced by climatic alteration. Levantine basin (Eastern Mediterranean Sea) is characterized by high temperature and salinity, as well as low nutrient levels, making it a challenging biological niche which constantly tests species' tolerance limits to physical components (Parari, 2009).

As the Red sea is characterized by generally higher temperatures than the Mediterranean, a rise in average water temperature in the Mediterranean waters can offer an adaptive advantage to invasive species, causing the displacement of other endemic species. Invasive species enter into the Mediterranean Sea through the Gibraltar straits, the Suez Canal and by being carried in ballast water of ships. The Suez channel, from where the Lessepsian migratory species find their way from the Red Sea into the Mediterranean, is the most common route for migration of species to the Levantine basin (Figure 6-5). Biological invaders are considered a threat for endemic species, as they can present adjustment advantages, causing them to displace or replace naturally occurring species from their habitats. Such examples of invasive species in Cyprus are the recent sightings of *Lagocephalus suezensis* which appear to be growing in numbers, *Caulerpa racemosa*, *Siganus luridus*, *Siganus rivulatus*, *Etrumeus teres*, *Fistularia commersonii* and a lot of other species. Up to 2010, a total of 133 alien species were recorded in Cyprus (30 fish, 44 molluscs, 19 polychaetes, 15 phytobenthic species, 12 crustaceans and 13 species from other taxa). Of these, 109 are Lessepsian (105 of Indo-Pacific origin, 4 cosmopolitan or circumtropical) (EastMed, 2010).

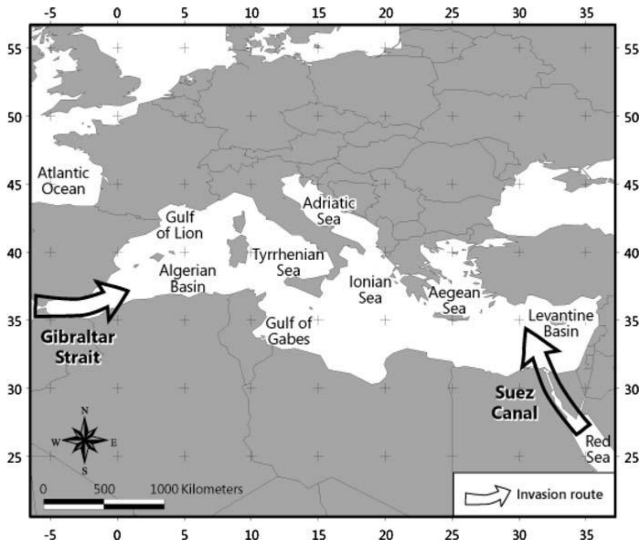


Figure 6-5: Geographical location of the Mediterranean Sea and routes of invasion (indicated by arrows)

Source: Increasing southern invasion enhances congruence between endemic and exotic Mediterranean fish fauna (Ben Rais Lasram & Mouillot, 2009)

Other than invasive species, local biodiversity is also threatened by immediate changes taking place as a result of climate change. Parameters such as the shift of ocean currents, the changes in salinity and the ocean acidification are estimated to be the main reasons for the observed changes in the phytobenthos and phytoplankton of the Mediterranean Sea, where Cyprus is located. For example, marine habitats of neuralgic importance -such as *Posidonia oceanica* meadows- are very sensitive to salinity, temperature and sedimentation alterations. The meadows produced by this marine plant function as nursery grounds for juvenile fish, reproductive fields and fisheries stock replenishment areas are exceptionally important. A potential loss of these meadows would bring catastrophic consequences for the marine biodiversity of Cyprus and its commercial fisheries (Parari, 2009).

6.3.2.2 Freshwater biodiversity

Climate change affects the inland aquatic biodiversity. Climate change can cause enhanced phytoplankton bloom, favoring and stabilizing the dominance of harmful cyanobacteria in phytoplankton communities, resulting in increased threats to the ecological status of lakes and enhanced health risks, particularly in water bodies used for public water supply and bathing (EEA, JRC, WHO, 2008).

Furthermore, a warmer climate will generally intensify some phenomena caused by human activities such as alterations to the host environment due to the introduction of new fish species for sport fishing, or eutrophication due to the increased loads of artificial or natural substances. More specifically for eutrophication, temperature rise will increase mineralization and releases of nitrogen, phosphorus and carbon from soil organic matter and increase run-off and erosion, which will result in increased pollution transport. Also release of phosphorus from bottom sediments in stratified lakes is expected to increase, due to declining oxygen concentrations in the bottom waters (EEA, JRC, WHO, 2008).

In Cyprus:

In Cyprus, the plants, fish and aquatic organisms of rivers and lake dams of Cyprus are generally in good condition, whereas the organisms of the groundwaters are more strained.

The nitrogen pollution from untreated sewage effluent and agricultural run-off carrying fertilizers iis responsible for the phenomenon of eutrophication, which can possibly be deteriorated by climate change. The areas identified as vulnerable to nitrogen pollution, according to the Nitrates Directive 91/676/EEC (Vulnerable Nitrate Zones), are the aquifers of Kokkinohoria, Kiti-Pervolia, Akrotiri, Paphos, Poli Chrisohous and in the more recently added area of Orounta (DoA, 2011). The areas 'Polemidhia Storage Reservoir' and the coastal area between Cape Pyla and Paralimni have been identified as sensitive according to the Directive Urban Wastewater Treatment Directive 91/271/EEC (WDD, 2011). Another area sensitive to nitrogen and phosphorus pollution is the recorded location in Larnaca, where the seabed (muddy sand with Caulerpa) is degraded (Ramos et al., 2007).

In order to extract safe conclusions regarding the impact of climate changes on freshwater biodiversity, the following are considered necessary:

- Determination of the change in the size and bloom of phytoplankton and relevant aquatic organisms
- Evaluation of the oxygen content in waters
- Correlation with climatic conditions and clear distinction of the effect from human activities

6.3.2.3 Phenology of aquatic ecosystems

Changes in aquatic phenology have been estimated that are affected by climate factors, such as the temperature rise and the degree and speed of regional climate change. One of the most important effects is the change in the size and bloom of phytoplankton. The impact of weather on the intensity of ocean mixing (and its reverse ocean stratification) affects the light levels, surface temperature and magnitude of nutrient recycling from deep layers, thereby influencing phytoplankton growth and bloom by driving bottom-up processes (i.e. the role of members of one trophic level as food items for higher trophic levels) throughout the pelagic food chain (Hays, Richardson, & Robinson, 2005).

In addition, impacts of increased water temperatures may also include more stable vertical stratification of deep lakes and increased oxygen depletion in lake bottoms, more frequent harmful algal blooms, reduced habitats for cold-water aquatic species, and increased incidence of temperature-dependent diseases (EEA, JRC, WHO, 2008).

Other impacts of temperature rise are eutrophication, reduction of oxygen content and increase in the biological respiration rates and lower levels of dissolved oxygen concentration. Long-term trends based on observational and satellite data indicate that global phytoplankton concentrations have declined about ~1% of the global median per year over the last century (ESSEA, 2010).

Furthermore, due to the fact that phytoplankton consumes carbon dioxide from the water during photosynthesis and emits oxygen as a by-product, it is obvious why a reduction of its amount is so important for the atmospheric concentration of carbon dioxide.

In Cyprus: Although an increased sea surface temperature (SST) has been confirmed, this has not been associated with the aquatic phenology of Cyprus.

In order to extract safe conclusions regarding the impact of climate changes on marine phenology, the following are considered necessary:

- Determination of the change in the size and bloom of phytoplankton
- Determination of the mixing pattern of the sea and nutrient recycling from deep layers
- Evaluation of the oxygen content
- Determination of the mixing pattern of the freshwater bodies nutrient recycling from deep layers
- Correlation with climatic conditions and clear distinction of the effect from human activities

6.4 Vulnerability assessment

In this section, the vulnerability of biodiversity to climate change impacts is assessed in terms of their sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which biodiversity is affected by climate changes, exposure is the degree to which biodiversity is exposed to climate changes and their impacts while the adaptive capacity is defined by the ability of biodiversity to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The indicators used for the assessment of sensitivity, exposure and adaptive capacity of Cyprus biodiversity to climate change impacts are summarized in Table 6-8.

Table 6-8: Indicators used for the vulnerability assessment of climate change impacts on the biodiversity of Cyprus

Vulnerability Variable	Selected indicators
Distribution of plant species in terrestrial ecosystems	
Sensitivity	– Landscape fragmentations – Species richness – Percentages of the sensitive endemic plant species – Percentages of invasive plant species – Drought periods
Exposure	– Distribution of the critically endangered plant species on the island
Adaptive capacity	– Resilience of wild plants to the rate of climate change* – List with the Critically Endangered (CR) plants – Cleaning of some areas of the island from invasive plants – Law 24/1988 on the ratification of the Bern Convention on the conservation of European wildlife and natural habitats – Law 153(I)/2003 on the protection and management of nature and wildlife – Law 4(III)/1996 on the ratification of the Convention on Biological Diversity (1992). – Law 20/1974 on the ratification of the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES)
Distribution of animal species in terrestrial ecosystems	

Vulnerability Variable	Selected indicators
Sensitivity	– Landscape fragmentations – Temperature rise – Droughts – Food availability – Populations of animal species*
Exposure	– Loss of species* – Migration of species*
Adaptive capacity	– Genetic adjustment* – Uphill migration – List of endangered and threatened animal species – Designation of SCI/SPA areas – Law 24/1988 on the ratification of the Bern Convention on the conservation of European wildlife and natural habitats – Law 152(I)/2003 on the protection of wild birds and "controlled game" (Birds Directive 2009/147/EC) – Law 153(I)/2003 on the protection and management of nature and wildlife (Habitats Directive 92/43/EEC) – Law 20/1974 on the ratification of the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) – Law 17(III)/2001 on the ratification of the Bonne Convention on the conservation of Migratory Species of Wild Fauna. – Law 8 (III) / 2001 on the ratification of the Ramsar Convention – Law 4(III)/1996 on the ratification of the Convention on Biological Diversity (1992).
Marine biodiversity	
Sensitivity	– Number of invasive alien species* – Northward movement of marine species* – Variety of indigenous marine species – Low biomass – Changes in temperature, salinity and nutrient levels – Alien species*
Exposure	– Proximity to natural and manmade nautical channels which favor species migration and relocation – Marine zone
Adaptive capacity	– Genetic adjustment* – Recording of marine Invasive Alien Species – Ratification of the Barcelona Convention on the protection of Mediterranean Sea – Ratification of the Barcelona Convention – Protection of aquatic species through the provisions of national law

Vulnerability Variable	Selected indicators
	since 1971 – Law 24/1988 on the ratification of the Bern Convention on the conservation of European wildlife and natural habitats – Law 153(I)/2003 on the protection and management of nature and wildlife – Law 4(III)/1996 on the ratification of the Convention on Biological Diversity (1992). – The Fisheries Law and Regulations – Plan for the control of the population of Lagocephalus sceleratus (IAS) in the coastal waters of Cyprus – Subsidies through the National Strategy Plan for Fisheries 2007-2013 (reduction of fishing effort, use of more selective fishing gear, withdrawal of trawlers) – Law 13(I)/2004 on the protection and management of water resources enforcing the Water Framework Directive (2000/60/EC) – Mediterranean Action Plan (MAP) – Coastal Area Management Programme (CAMP)
Freshwater biodiversity	
Sensitivity	– Indigenous fish species – Indigenous plant species – Human activities – Stratification* – Oxygen depletion* – Water quality – Dominance of harmful cyanobacteria in phytoplankton communities* – Nitrogen and phosphorus pollution in surface waters
Exposure	– Perennial rivers – Number of lakes – Number of water bodies – Endangered plant species* – Endangered aquatic species*
Adaptive capacity	– Genetic adjustment* – Buffer zones of protection of the environment – Enforcement of good fertilization practices in agriculture – Repair of existing infrastructures – Law 24/1988 on the ratification of the Bern Convention on the conservation of European wildlife and natural habitats – National law on the protection of aquatic species of inland and marine waters since 1971 and its related regulations – Ratification of the Barcelona Convention on the protection of Mediterranean Sea – Law 20/1974 on the ratification of the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES)

Vulnerability Variable	Selected indicators
	– Law 4(III)/1996 on the ratification of the Convention on Biological Diversity (1992). – Law 13(I)/2004 on the protection and management of water. – Law 34/2002 on the nitrogen pollution of waters (based on the European Directive 91/676/EEC). – Law 42/2004 on the control of nitrogen polluted waters. – Law 41/2004 on the control of water pollution. – Law 517/2002 on the control of water pollution. – Law 56(I)/2003 on waste management. – Law 108(I)/2004 on sewerage systems. – Law 772/2003 on urban wastewater. – Law 254/2003 on the nitrogen pollution of waterbodies. – Law 106(I)/2002 on the control of the water and soil pollution. – Captive breeding program in order to manage the problem of the artificial introduction of exotic fish in the dams of Cyprus

* No date available for this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability is assessed for the impact categories presented in Section 6.3:

1. Distribution of plant species in terrestrial ecosystems
2. Distribution of animal species in terrestrial ecosystems
3. Marine biodiversity
4. Freshwater biodiversity

It is noted that, the vulnerability of “Plant phenology of terrestrial ecosystems”, “Animal phenology of terrestrial ecosystems” and “Phenology of marine ecosystems” was not assessed due to lack of relevant research findings.

The vulnerability of biodiversity varies substantially as it is related to the different rate and magnitude of climate change in different parts of Cyprus due to the variability of the air pollution levels, altitude, temperature and rainfall variations, meteorological conditions (e.g. wind, moisture), local geomorphology and soil characteristics.

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability. In case additional data are provided by the competent authorities of Cyprus, the vulnerability of the sector could be re-assessed.

6.4.1 Terrestrial ecosystems

6.4.1.1 Distribution of plant species in terrestrial ecosystems

6.4.1.1.1 Assessment of sensitivity and exposure

Sensitivity

The general characteristics of the plant distribution in Cyprus which reveal an environment of sensitive to climate change plant species are the following: (i) low species richness, (ii) sensitive endemic plant species and (iii) several invasive plant species.

i) Low species richness

The number of plant species in Cyprus is generally considered low in comparison with the levels in Europe (Figure 6-6 and Figure 6-7), perhaps due to the semi-arid climate of the island and the more frequent presence of consecutive years of droughts.

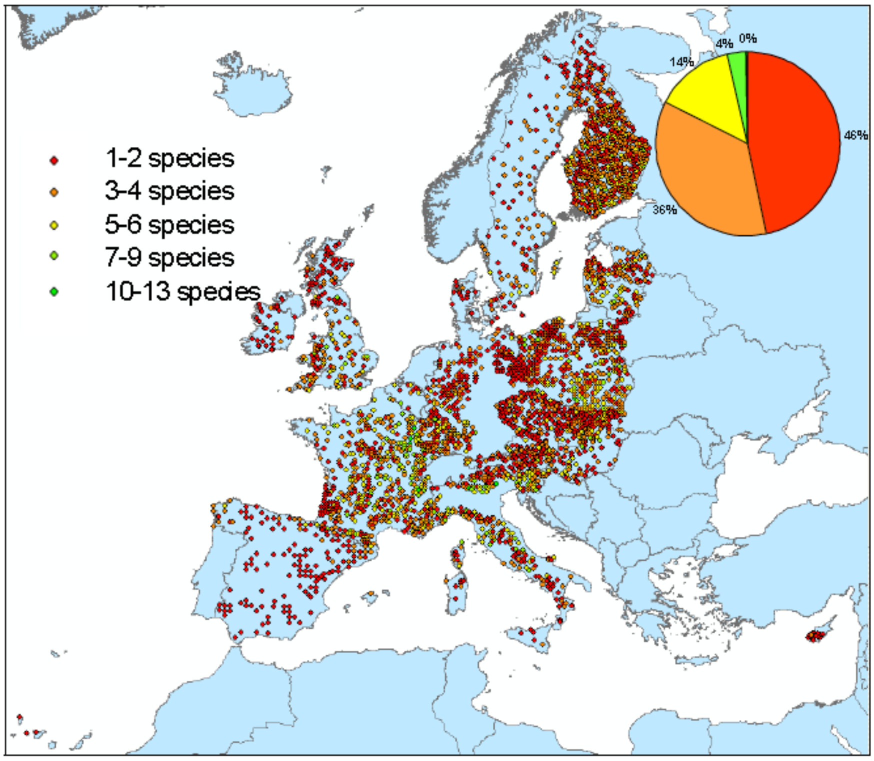


Figure 6-6: Species richness according to the European Forest Type Classification score (EFTC)

Source: Evaluation of BioSoil Demonstration Project Preliminary Data Analysis (Hiederer & Durrant, 2010)

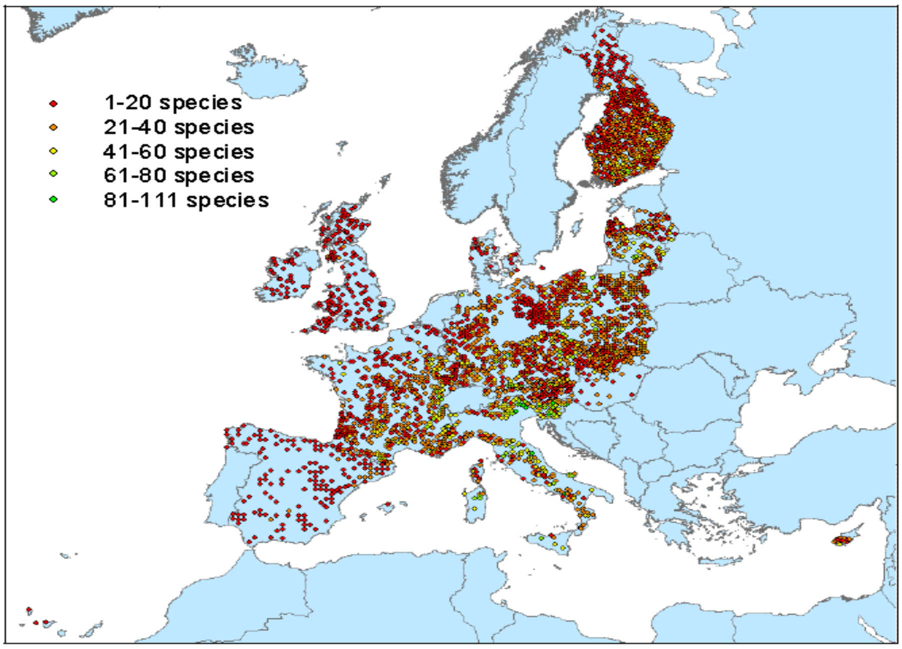


Figure 6-7: Ground vegetation species richness

Source: Evaluation of BioSoil Demonstration Project Preliminary Data Analysis (Hiederer & Durrant, 2010)

ii) Sensitive endemic plant species

The more sensitive plant species are considered those that belong to relic populations and those that are less capable to adapt in the new environmental conditions. The populations in mountain ecosystems are more sensitive, due to the global phenomenon of uphill tree line migration and the landscape fragmentations (Kullman, 2006; Kullman, 2007; Pauli et al., 2007; EEA, JRC, WHO, 2008). Forests in Cyprus cover mountain areas equivalent to the 16.7% of the total surface of the island. As a result, the forests of Cyprus are particularly sensitive to climate change.

More specifically, according to the Red Book of Flora of Cyprus (Tsintides et al., 2007), 7% of the plant taxa in Cyprus is Regionally Extinct (RE/?RE), 14% of endemic plants of Cyprus is characterized as Critically Endangered (CR), 19,5% as Endangered (EN), 39% as Vulnerable (VU), 4,6% as Close Threatened (NT) and 2,2% as Low Danger (LC) (Figure 6-8).

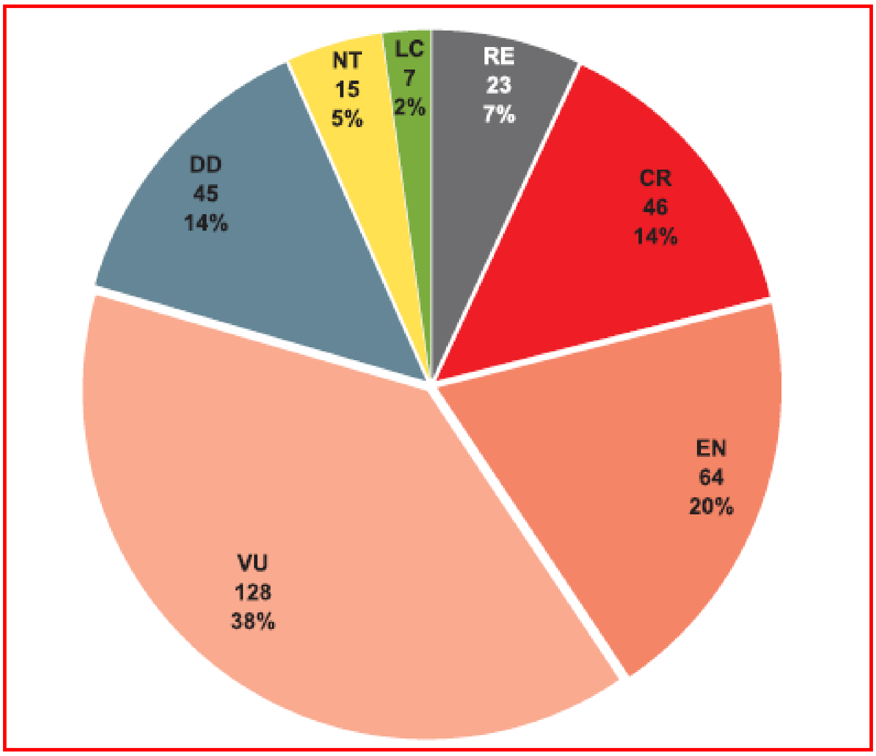
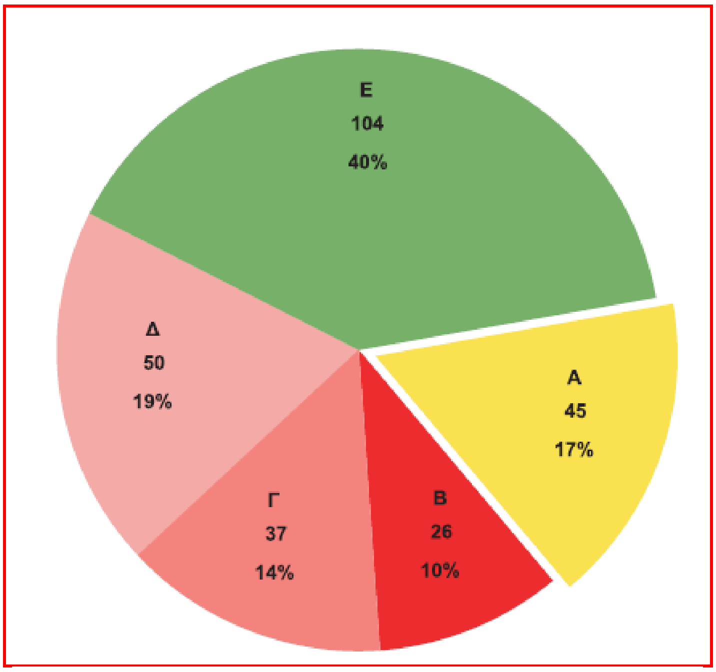


Figure 6-8: Distribution of evaluated plant taxa in the IUCN Read List Categories

Source: The Red Data Book of the Flora of Cyprus (Tsintides et al., 2007)

In addition, an important percentage of the endemic plants of Cyprus, which are characterized as Critically Endangered (CR) (Table 6-9), can only be found in Cyprus or in other three countries at most (Figure 6-9 and Table 6-9).



A: Cyprian endemic,

B: near endemic (plant occurring in Cyprus and at most, in three other countries),

Γ: east-Mediterranean, Mediterranean,

E: wider distribution (plant with distribution range extending beyond the Mediterranean)

Figure 6-9: Chorology of the threatened and extinct plants

Source: The Red Data Book of the Flora of Cyprus (Tsintides et al., 2007)

Table 6-9 : List with the Critically Endangered (CR) plants of Cyprus

Plant Species	Location
Arabis kennedyae Meikle	Troodos, Triptilos(in altitude 900-1350m)
Astragalus macrocarpus subsp. lefkarensis Agerer-Kirchhoff & Meikle	Only in Cyprus in Leykara, Asgata, Alaminos and Kelokedara.
Centaurea akamantis T. Georgiadis & G.Chatzikyriakou	Only in Akamas of Cyprus.
Delphinium caseyi B. L. Burtt	Only in Cyprus, in Pentadaktylos (tops of Saint Ilarionas and Kyparrissovouno)
Scilla morrisii Meikle	Exclusively at southwest of Cyprus (Monastiri, Agia Moni, Saint Neofytos)
Salvia veneris Hedge	West of Kithreas villages
Erysimum kykkoticum G. Hadjikyriakou & G. Alziar	One the rarest endemic species. It is located in the valley of Xeros (Agrakin of Pissokremmou)

Source: The top 50 plants of the Mediterranean Island Plants (de Montmollin & Strahm, 2005)

iii) Invasive plant species

According to the studies of Georgiades (1994) and Hadjikyriakou & Hadjisterkotis (2002), 152 adventive species have been recorded (Unit of Environmental Studies)(Table 6-10). More specifically, the *Acacia saligna (Labill.) (H.Wendl.)* is described as the most dangerous invasive species in Cyprus, threatening many natural habitats, invading maquis, garigue, phrygana, marshy areas and agricultural land. It has been recorded as a serious threat to the habitat of the salt lake of Larnaca and it was considered necessary to remove a number of its population from the area (Atlantis Consulting Cyprus Ltd). Likewise, the *Robinia pseudoacacia* L. has spread in forests, maquis, garigue and phrygana vegetation. In addition, the observed for the first time *Ailantus altissimma* (Mill.) *Swingle and Casuarina cunninghamiana* Miq. is also spreading, threatening natural habitats such as forests and maquis.

Table 6-10: List of the 16 adventive species spreading to natural habitats and the observed for the first time adventive species also spreading to natural habitats

Adventive species spreading to natural habitats	Adventive species, observed for the first time, spreading to natural habitats
1. *Vinca major L.* 2. *Cistus ladanifer L.* 3. *Tagetes minuta L.* 4. *Tanacetum balsamita L.* 5. *Tanacetum parthenium (L.)* Sch.Bip. 6. *Corylus maxima Mill.* 7. *Iris albicans* Lange 8. *Acacia saligna (Labill.)* H.Wendl. 9. *Robinia pseudoacacia L.* 10. *Epilobium angustifolium L.* 11. *Oxalis pes-caprae L.* 12. *Eschscholzia californica* Cham. 13. *Papaver somniferum L.* 14. *Dodonaea viscosa (L.)* Jacq. 15. *Antirrhinum majus L.* 16. *Vitis vinifera*	1. *Celtis australis L.* 2. *Cercis siliquastrum L.* 3. *Prunus dulcis* (Mill.) D.A.Webb 4. *Ailantus altissimma* (Mill.) *Swingle and Casuarina cunninghamiana Miq.*(its spreading status threatens natural habitats invading forests and maquis) 5. *Fraxinus angustifolia Vahl* subsp. *Angustifolia* 6. *Pyrus malus* L. 7. *Prunus persica* (L.) Batasch

Source: Review of biodiversity research results from Cyprus that directly contribute to the sustainable use of biodiversity in Europe (Unit of Environmental Studies)

Considering the above, the sensitivity of the distribution of plant species (including Invasive Alien plant Species) in Cyprus is **high**.

<u>*Exposure*</u>

The distribution of the critically endangered plant species (Table 6-9) on the island, seems to be in many and scattered areas such as Madari, Akamas peninsula, Akrotiri peninsula, cape

Greko and in some potential areas[23] such as the mountains (the National Forest of Troodos, the National Forest of Paphos and Pentadaktylos) (Figure 6-10). As a result the "exposure" can be characterized as **high**.

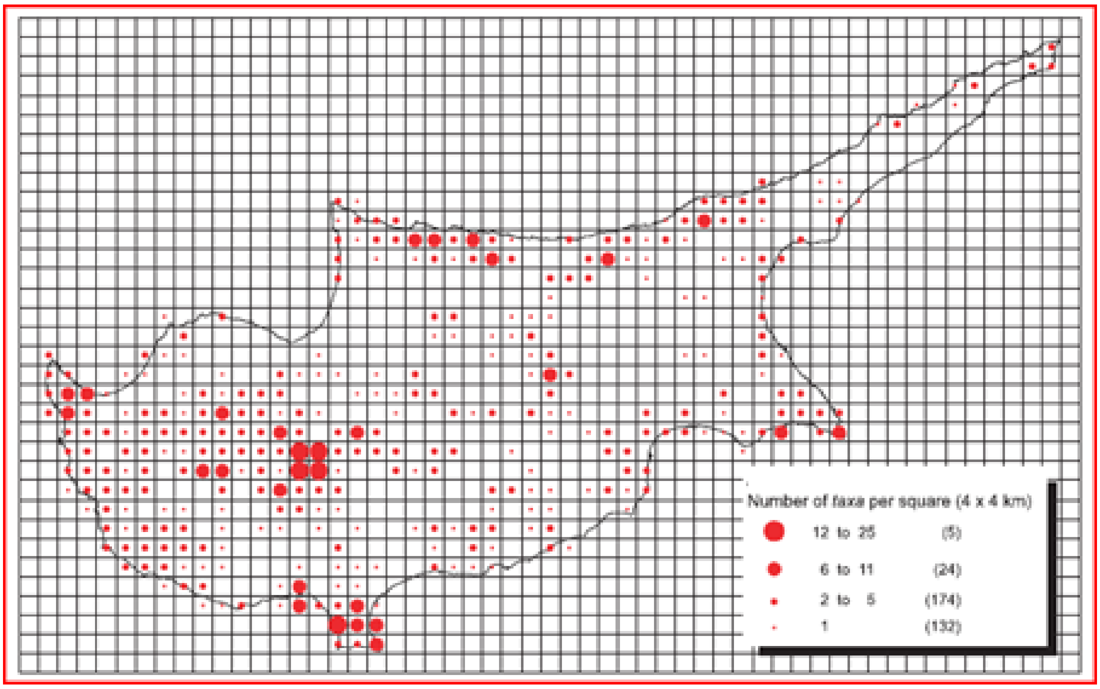


Figure 6-10: Geographic distribution of the threatened plants of Cyprus

Source: The Red Data Book of the Flora of Cyprus (Tsintides et al., 2007)

6.4.1.1.2 Assessment of adaptive capacity

The resilience of plants towards climate change refers to their ability to genetically adjust to changing environmental conditions as well as to their ability for uphill migration. However, more research in this field is necessary to be done. In addition, the government of the Republic of Cyprus has recorded the flora species of the island (Red Data Book), and has transposed to the national legislative framework (i) the Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (with the Law 153(I)/2003), (ii) the ratification of the Bern Convention on the conservation of European wildlife and natural habitats (with the Law 24/1988), (iii) the Convention on International Trade in Endangered Species of Wild Fauna and Flora, (iv) CITES (with the Law 20/1974) and (v) the Convention on Biological Diversity (with the Law 4(III)/1996). The protection status of the endangered plant species in Cyprus is presented in the following table (Table 6-11).

[23] The populations in mountain ecosystems are more sensitive, due to the global phenomenon of uphill tree line migration (Kullman, 2006; Kullman, 2007; Pauli et al., 2007; EEA, JRC, WHO, 2008).

Table 6-11 : Protection status of the endangered plant species in Cyprus

Plant Species	Measures
Arabis kennedyae Meikle	1.Annex I, Bern Convention 2. Annexes II, IV, European Habitat Directive. 3. Red Data Book of the Flora of Cyprus
Astragalus macrocarpus subsp. lefkarensis Agerer-Kirchhoff & Meikle	
Centaurea akamantis T. Georgiadis & G.Chatzikyriakou	
Delphinium caseyi B. L. Burtt	
Scilla morrisii Meikle	
Salvia veneris Hedge	1.Under the protection of the legislation for the National Forest of Lakkovounara 2. Annex I, Bern Convention 3.Annexes II, IV, European Habitat Directive 4. Red Data Book of the Flora of Cyprus
Erysimum kykkoticum G. Hadjikyriakou & G. Alziar	1.Under the protection of the legislation for the National Forest of Paphos 2. Red Data Book of the Flora of Cyprus

Source: The top 50 plants of the Mediterranean Island Plants (de Montmollin & Strahm, 2005)

However, it must be noted that the abovementioned legislative measures aim mainly to reduce human pressures posed on biodiversity, while little can be done to reduce the effects from adverse climate conditions.

Regarding the spreading of harmful invasive species is addressed with localized actions, as for example the Action Plan for the planting control and eradication of the Invasive Alien Species of *Acasia* in Natura 2000 areas. The plan was completed with great success.

Considering the above, the adaptive capacity can be considered **limited to moderate**.

6.4.1.2 Distribution of animal species in terrestrial ecosystems

6.4.1.2.1 Assessment of sensitivity and exposure

Sensitivity

According to the studies conducted by Levinsky et al (2007) and Lemoine et al. (2007), widespread species may be less vulnerable while threatened endemics –which are already under pressure- will be at greatest risk despite their spatial variation (EEA, JRC, WHO, 2008). Furthermore, the inability of migrating to other habitats represents an important constraint for many species, either due to landscape fragmentations or because of their physical characteristics. Therefore, it was considered that the sensitivity of animal distribution to climate changes for the island of Cyprus is **high**.

Exposure

Based on the conclusions of the World Resources Institute for the period 2002-2003, the most threatened species -in terms of population number- are located in terrestrial environments as shown in Figure 6-11. Some of the most endangered species are the Cyprus muflon (*Olcis orientalis ophion*), the *Rousettus aegyptiacus*, 332 migratory species, the bird Griffon, the snake *Columber cypriensis* and 11 more terrestrial reptiles. Consequently the exposure can be considered **high**.

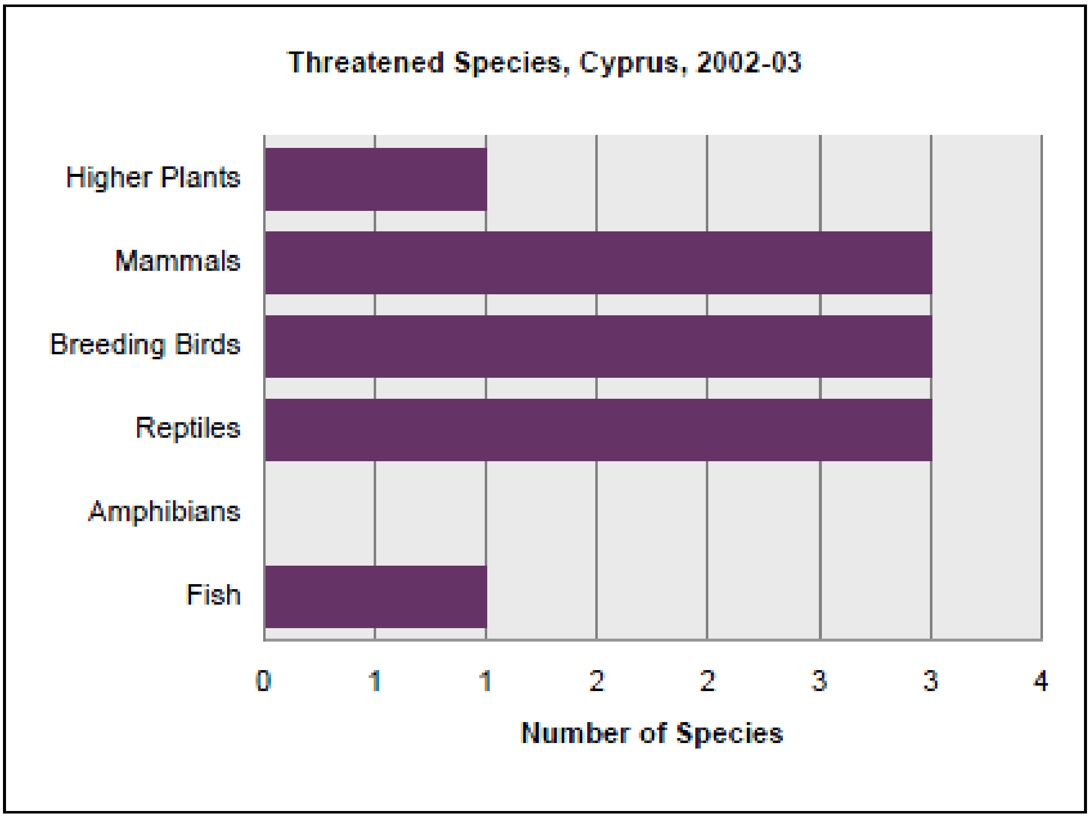


Figure 6-11: Threatened Species in Cyprus, 2002-03

Source: Biodiversity and Protected Areas-Cyprus (World Resources Institute)

6.4.1.2.2 Assessment of adaptive capacity

The resilience of animals towards climate changes refers to their ability to genetically adjust to changing environmental conditions as well as to their ability for uphill migration. There are no data available for the animal population movements in Cyprus. In addition, the government has taken measures such as the transposition to the national legislative framework of the Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (with the Law 153(I)/2003) and the Directive 2009/147/EC on the conservation of wild birds (with the Law 152(I)/2003) as well as the ratification of the Bern Convention on the conservation of European wildlife and natural habitats (with the Law 24/1988), the Bonn Convention on the conservation of migratory species of wild animals (with the Law 17(III)/2001) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES (with the Law 20/1974) and the Convention on Biological Diversity (with the Law 4(III)/1996). The protection status of the endangered animal species of the terrestrial ecosystems in Cyprus is presented in the following table (Table 6-12).

Table 6-12: Protection status of the endangered animal species of the terrestrial ecosystems in Cyprus

Protected fauna species		Measures
Reptiles	*Mauremys caspica*	Protected under Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
	Coluber cypriensis - EN	Protected under Annex II* and IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
	Emys orbicularis	Annex II of Bern Convention
	10 other species	Protected under Annex II of Habitats Directive 92/43/EEC
Birds	*Numenius tenuirostris*	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Pelecanus crispus - VU	Protected under Annex II of SPA protocol [1]
	Oxyura leucocephala - EN	Protected under Annex II of Bern Convention
	Branta ruficollis - VU	Protected under Annex II of Bern Convention
	Crex crex - LR	Protected under Annex II of Bern Convention
	Emberiza aureola	Protected under Annex II of Bern Convention
	Gallinago media	Protected under Annex II of Bern Convention
	Larus audouinii - LR	Protected under Annex II of Bern Convention
	Emberiza cineracea	Protected under Annex II of Bern Convention
Mammals	*Ovis orientalis ophion* (Cyprus muflon) – VU	Protected under Annex II* and IV of Habitats Directive 92/43/EEC
	Rhinolophus Euryale - VU	Protected under Annex II of Habitats Directive 92/43/EEC
	Capra aegagrus (Cyprus goat) - VU	Protected under Annex II and IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
	Rousettus aegyptiacus	Protected under Annex II and IV of Habitats Directive 92/43/EEC

Source: Hadjichristophorou, 2000; DoE, 2010b; USAID, 2006

Nevertheless, the genetic adjustment of animals and the measures taken are not enough for combating the increasing risk of terrestrial animals towards climate change; hence the adaptive capacity of this factor for Cyprus is estimated as **limited to moderate**.

6.4.2 Aquatic ecosystems

6.4.2.1 Marine biodiversity

6.4.2.1.1 Assessment of sensitivity and exposure

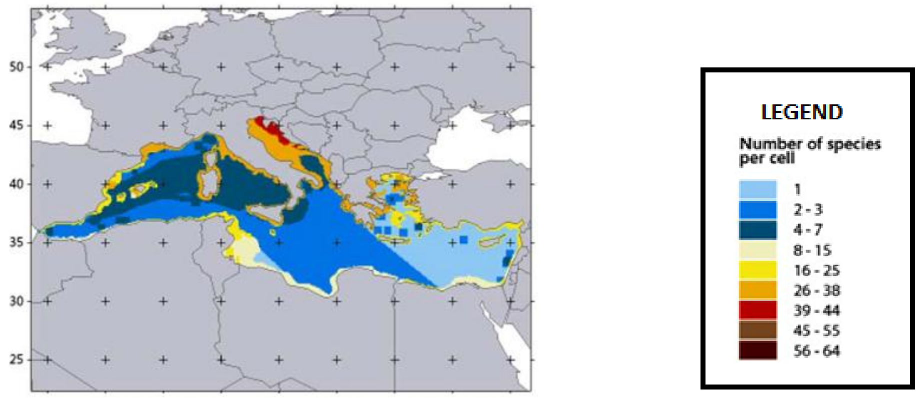
Sensitivity

The high Sea Surface Salinity (SSS) and Sea Surface Temperature (SST) of Cyprus in comparison with the rest of the Mediterranean region results in a relatively high species diversity (Figure 6-12a) and very low biomass. The sea around Cyprus has a diverse array of important habitats and hosts a considerable number of endangered species. The angiosperm *Posidonia oceanica*, which is endemic to the Mediterranean, forms extensive meadows along the coasts of Cyprus. The *Cymodocea nodosa* thrives in shallower waters while *Caulerpa prolifera*, *Halophyla stipulacea* and *Pinna nobilis* abound in deeper waters. In addition, several endangered marine species are accommodated in the coastal waters of Cyprus, such as the monk seal *Monachus monachus*, the marine turtles *Chelonia mydas* and *Caretta caretta*, the Triton Trumpet shell *Charonia tritonis*, the pen shell *Pinna nobilis* and many others (DoE, 2010b).

Temperature rise is the main reason for the northward movement of marine species, changing the composition of local and regional marine ecosystems (Brander et al., 2003; Beare et al., 2004; Beare et al., 2005; Perry et al., 2005; Stebbing et al., 2002; EEA, JRC, WHO, 2008). These changes in combination with some physical characteristics, such as the variety of indigenous marine species and the low biomass, make sensitivity to climate change even higher affecting the distribution of fish and the socioeconomic situation for local fishermen.

The increasing intrusion of exotic fish in the Mediterranean Sea (Figure 6-12 b,c) has not yet been determined whether it constitutes a serious threat for the extinction of the endemic species (Ben Rais Lasram & Mouillot, 2009) or has been underestimated (Zenetos et al., 2008), but what has been proved is that the northward movement of species is affected by the global warming.

(a)



(b) (c)

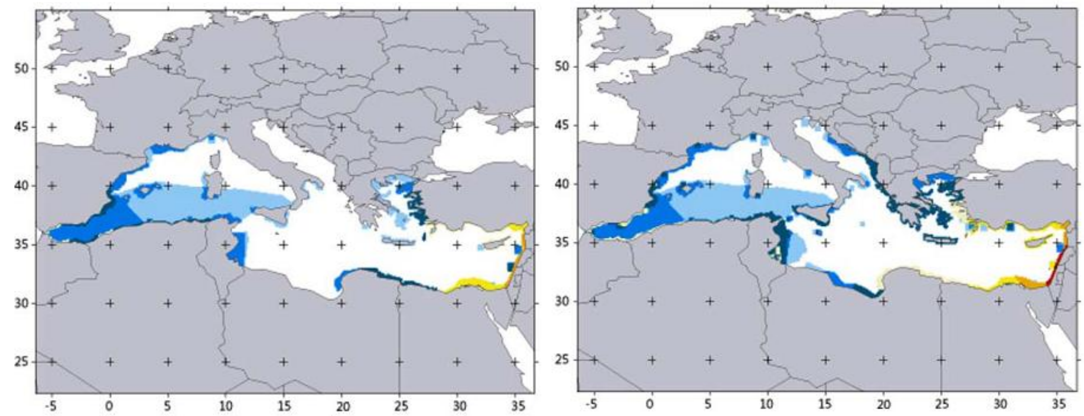


Figure 6-12: Maps illustrating the patterns of diversity (number of species per cell) for endemic fish species (a), for exotic species during the eighties (b) and for exotic species in 2006 (c)

Source: Increasing southern invasion enhances congruence between endemic and exotic Mediterranean fish fauna (Ben Rais Lasram & Mouillot, 2009)

The number of invasive species introduced in the coastal and offshore waters of Cyprus has grown over the last 50 years, as shown in the following figure (Figure 6-13). Studies have shown that the rate of new biological invasions in the Mediterranean Sea is as high as 1 new species every 9 days (Zenetos et al., 2008). Consequently the sensitivity can be considered **moderate**.

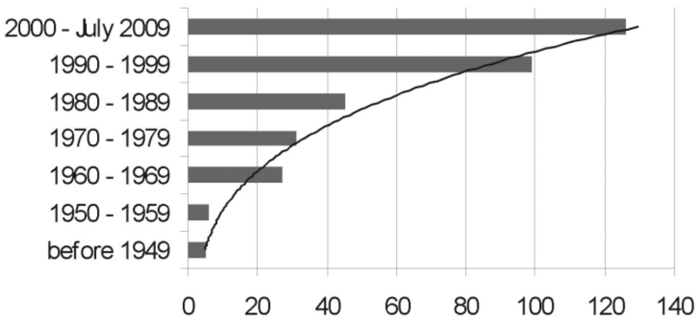
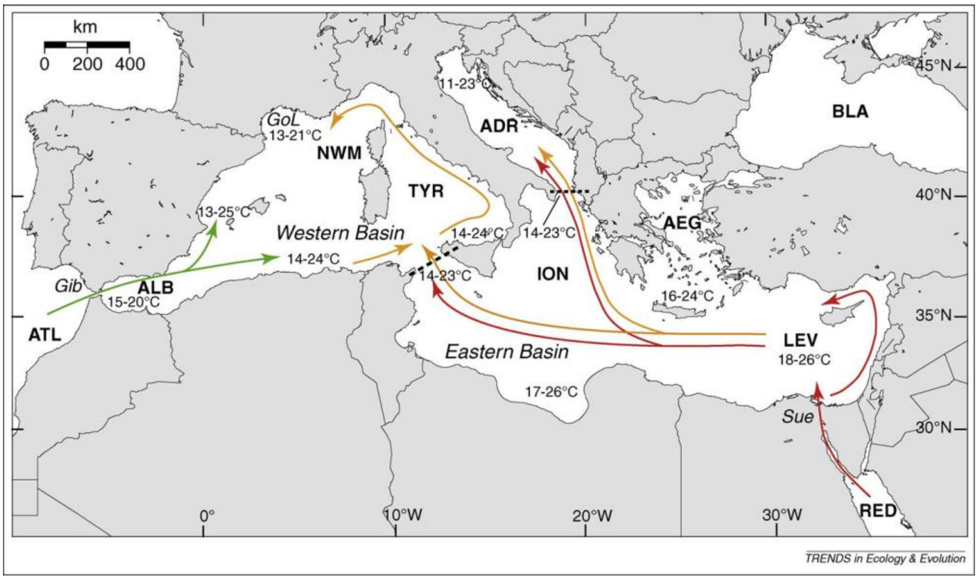


Figure 6-13: Cumulative number of alien marine species in Cyprus per decade, based on the reported year sighting

Source: Inventory of alien marine species of Cyprus (Katsanevakis et al., 2009)

Exposure

The number of alien biota in the Mediterranean Sea appears to be underestimated. Some hot spot areas for possible species introductions, such as the coasts of the Levantine basin, are not well studied (Zenetos et al., 2005). The Mediterranean Basin is characterised as a receptacle for exotic species while being a hotspot for endemism. The increasing southern invasion enhances congruence between endemic and exotic Mediterranean fish fauna (Ben Rais Lasram & Mouillot, 2009), which has been confirmed by the increased successful introductions from the Red Sea and lower latitudes of the Atlantic and the increasing overlap between the spatial distributions of endemic and exotic species richness (Figure 6-14), all of which are correlated to the temperature rise. Cyprus is located near the manmade nautical channel of Suez which favours the migration and relocation of the Lessepsian species, hence the “exposure” can be characterized as **high to very high**.



Bold capital abbreviations correspond to the main Mediterranean sub-regions (ALB: Alboran Sea; NWM: North Western Mediterranean; TYR: Tyrrhenian Sea; ADR: Adriatic Sea; ION: Ionian Sea; AEG: Aegean Sea; LEV: Levantine Basin) and adjacent seas (ATL: Atlantic Ocean; BLA: Black Sea; RED: Red Sea). Italic abbreviations correspond to some remarkable Mediterranean locations (Gib: Gibraltar Straits; GoL: Gulf of Lions; Sue: Suez Canal). Reported temperatures correspond to winter–summer mean sea-surface temperatures. Arrows represent main routes of species range expansion according to their origin: Mediterranean natives (orange), Atlantic migrants (green) and Lessepsian migrants (red).

Figure 6-14: Geography of the Mediterranean Sea with the main routes of species range expansion

Source: Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea (Lejeusne et al., 2009)

6.4.2.1.2 Assessment of adaptive capacity

Scientific recording of the populations of marine species reveals some[24] of the extent of the threat for the marine host species. The genetic adjustments of the host organisms to new conditions need many reproductive cycles, and as a result the most common way of survival is the migration to other latitudes.

In addition, there are numerous institutional measures for the protection of marine ecosystems. In Cyprus, there are six marine protected areas, including the coastal protected area of Lara-Toxeftra, which encompasses the most important breeding biotope for the sea turtles (*Chelonia mydas* and *Caretta caretta*). The area is protected since 1989 by the Fisheries Law and related regulations. The areas are protected by the 'Natura 2000' network (DoE, 2010) under the supervision of the Department of Fisheries and Marine research, Ministry of Agriculture, Natural Resources and Environment.

[24] *"The biased scientific interest towards taxa with well-known taxonomy and established historical distribution records (e.g. benthic organisms, fish) coupled with the chaos in nomenclature and fragmentary and sporadic information have led to a possible underestimation of the extent of aliens' presence particularly of the small, less-conspicuous, less-studied speci*es" (Zenetos et al., 2008).

Figure 6-15: Marine protected areas of Cyprus

Source: Department of Fisheries and Marine Research, 2012

In Cyprus, the protection of aquatic species of inland and marine waters, is implemented through the provisions of national law since 1971 and its related regulations, as well as through the Law 153(I)/2003 which harmonizes Directive 92/43/EEC on the Conservation of Natural Habitats and Wild Fauna and Flora. In addition, Cyprus has ratified the Barcelona Convention for the Protection of the Mediterranean Sea against Pollution and in particular the SPA Protocol concerning Specially Protected Areas and Biodiversity in the Mediterranean. Complementary to these are the Convention on Conservation of European Wildlife and Natural Habitats (Bern Convention), the Convention on the International Trade in Wild Fauna and Flora (CITES) and the Convention on Biological Diversity (CBD). In particular, protected marine species and habitats are those listed in the aforementioned Directives and Conventions, as well as those in the Fisheries Law and Regulations, including all species of sea turtles, dolphins, seals and a species of sand crab (DoE, 2010), as shown in Table 6-13.

Table 6-13: Protected fauna aquatic species in Cyprus

Protected fauna species		Measures
Fish	Aphanius fasciatus	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Hippocampus hippocampus	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Hippocampus ramulosus	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention

Protected fauna species		Measures
	Mobula mobular - VU	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Carcharodon carcharias - VU	Annex II of SPA protocol [1], Annex II of Bern Convention
Mammals	Monachus monachus – CR	Annex II of SPA protocol [1], Annex II of Bern Convention
	Delphinus delphis – EN	Annex II of SPA protocol [1], Annex II of Bern Convention
	Stenella coeruleoalba	Annex II of SPA protocol [1], Annex II of Bern Convention
	Tursiops truncatus	Annex II of SPA protocol [1], Annex II of Habitats Directive 92/43/EEC, Annex II of Bern Convention
Reptiles	Caretta caretta - EN	Protected under Annex II of SPA protocol [1], Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
	Chelonia mydas - CR	Protected under Annex II of SPA protocol [1], Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
	Natrix natrix cypriaca	Protected as freshwater fauna under the Fisheries Regulations (Reg. 273/90)
Amphibia	Bufo viridis	Protected under Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention, Fisheries Regulations (Reg. 273/90)
	Hyla savignyi	Protected as freshwater fauna under the Fisheries Regulations (Reg. 273/90)
Arthropods	Ocypode cursor	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Potamon potamios	Specifically protected under national legislation
	Artemia salina	Specifically protected under national legislation
Molluscs	Charonia tritonis	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Erosaria spurca (Cypraea spurca)	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Luria lurida	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Tonna galea	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Lithophaga lithophaga	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Pholas dactylus	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Pinna nobilis	Protected under Annex II of SPA protocol[1], Annex IV of Habitats Directive 92/43/EEC
Echinoderms	Asterina panceri	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Ophidiaster ophidianus	Protected under Annex II of SPA protocol [1], Annex II of Bern Convention
	Centrostephanus longispinus	Protected under Annex II of SPA protocol[1], Annex IV of Habitats Directive 92/43/EEC, Annex II of Bern Convention
Porifera	Axinella polypoides	Protected under Annex II of SPA protocol [1]

Protected fauna species		Measures
	Axinella cannabina	Protected under Annex II of SPA protocol [1]
	Geodia cydonium	Protected under Annex II of SPA protocol [1]

IUCN categorization: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Low Risk (LR)

[1] *Protocol concerning Specially Protected Areas and Biodiversity in the Mediterranean –Barcelona Convention*

Source: Hadjichristophorou, 2000; DoE, 2010b; USAID, 2006

In addition, a number of research and monitoring programs focusing on the marine biodiversity conservation and protection of endangered habitats and species (e.g. *Posidonia oceanica*, turtles etc.), the designation of Marine Protected Areas and the assessment of the ecological status of coastal waters within the framework of the Water Framework Directive (2000/60/EC) are undertaken. Furthermore, the Oceanography Centre of the University of Cyprus is currently participating in two Mediterranean-wide projects (Tropical Signals and JellyWatch) of CIESM (the Mediterranean Science Commission) focusing on marine biodiversity and its impacts from climate change.

Additionally, action plans are taking place in relation to the protection of Cyprus due to the Mediterranean Action Plan (MAP) and the enforcement of its regulations and actions, in order to protect the biodiversity and development of coastal and marine areas (species, habitats, and landscapes) integrating the special development strategies under the Coastal Area Management Programme (CAMP) in a pilot area of the island. The program serves a dynamic process for the sustainable use and management of the coastal and marine areas and resources (DoE, 2010).

Finally, the Department of Fisheries and Marine Research, taking into account the reports from fishermen regarding the substantial increase and spread of the population of the IAS of Lagocephalus and the damage caused to the fishing gear and catches, prepared a study on the species in the coastal waters of Cyprus. After evaluating the results of the study, the DMFR developed a management plan entitled "Plan for the control of the population of Lagocephalus sceleratus in the coastal waters of Cyprus", and in 2012 announced the call for proposals for the implementation of the plan in the framework of the "Project Grants for collective actions in the Fisheries Sector". The purpose of the call is to eliminate the populations of lagocephalus from the coastal commercial fleet of Cyprus, with the exercise of intense fishing pressure on breeding population of the species, just before and during the breeding season, in the main breeding areas of the species.

Another interesting intervention was the captive breeding program by Dr. Birgit Blosat, who was hired by the government in order to manage the problem of the artificial introduction of exotic fish in the dams of Cyprus (Unit of Environmental Studies).

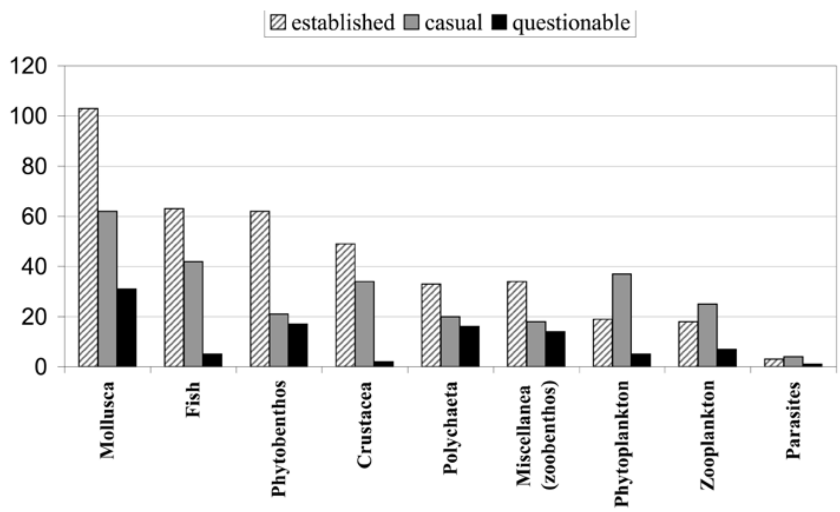
Furthermore, the marine and fisheries policy aims at the protection and conservation of the fish stock as well as of marine biodiversity. The foreseen measures within the National Strategy Plan for Fisheries 2007-2013 such as the reduction of fishing effort, the use of more selective fishing gear and the withdrawal of trawlers, incorporate the ecosystem approach.

These measures are undertaken in accordance with the EU Common Fisheries Policy and contribute to the minimization of the impact of fishing activities on the marine ecosystem and aim at promoting sustainability of marine resources.

There is a number of Laws and Regulations set in Cyprus that focus on issues such as the reduction of fishing intensity (hours and periods of fishing, types of networks, minimum allowable sizes for fishing marine organisms, technical restrictions on gear -number of hooks, length and height of nets, minimum distances from shore fishing and bottom fishing etc), the creation of protected fishing areas and habitats, the ban of certain fishing gear and practices, the application of restrictions on recreational fishing, the development of Management Plans and the management control of fishing shelters.

In addition, the Regulation 1967/2006/EC concerning management measures for the sustainable exploitation of fisheries resources in the Mediterranean Sea, has been gradually integrated to the Cyprus legislation. This is the most important Regulation containing technical measures, implementation of which has important consequences in the Cyprus fisheries. This include, inter alia, improvement of the fishing gear, the creation of management plans for specific fisheries (e.g. trawling) and the creation of protected areas for fisheries.

Overall, the designation of well-preserved important habitats along the coastal waters of Cyprus are evidence that the marine environment of Cyprus is still in a good state with minor environmental impacts (DoE, 2010b). Nevertheless, the increased number of successful intrusions of marine species in the area (Ben Rais Lasram & Mouillot, 2009) (Figure 6-16), indicates changes due to climate change.



Miscellanea (zoobenthos) include Foraminifera, Echinodermata, Ascidiacea, Cnidaria, Sipuncula, Pycnogonida, Enteropneusta, Porifera and Bryozoa.

Figure 6-16: Establishment success per ecofunctional Pycnogonida/taxonomic group

Source: Annotated list of marine alien species in the Mediterranean with records of the worst invasive species (Zenetos, et al., 2005)

Considering the above, the adaptive capacity can be characterized as **moderate**.

6.4.2.2 Freshwater biodiversity

6.4.2.2.1 Assessment of sensitivity and exposure

Sensitivity

The indigenous fish species richness in Cyprus is exceptionally poor and susceptible to numerous threats due to landscape fragmentations. The introduction of freshwater fish and crayfish in the artificial dams for recreation purposes altered the local environment and caused the reduction of the already endangered endemic grass snake *Natrix natrix cypriaca*. In addition, climate change strains in combination with the pollution caused by human activities stress water quality and aquatic populations. Nevertheless, indicators such as stratification or oxygen depletion could not be evaluated due to lack of information. Consequently the sensitivity can be considered as **high to very high**.

Exposure

The deterioration of water quality in Cyprus seems to be more extensive in the groundwater bodies than in the surface waters (which are limited due to the depleted aquifers and the parts of some rivers with continuous flow). The main matters which have arisen from the results of the monitoring of groundwater quality in Cyprus, were the increased nitrate and chloride concentrations (above the limits) which were found in seven water bodies, while another water body in Paphos is stll under investigation. In addition, increased concentrations of sulphates, ammonium, arsenic, pesticides and increased conductivity were found in several groundwater bodies. The main causes of pollution in Cyprus are agriculture, seawater intrusion and wastewater disposal, while industry constitutes a less significant source of pollution as the number of industries in Cyprus is limited. Moreover, the quality of groundwater in Cyprus is affected by natural causes like geological formations which release sulphate and chloride salts of sodium and boron. Furthermore, five (5) areas in Cyprus which drain into waters vulnerable to pollution from nitrogen compounds have been declared as Vulnerable Nitrate Zones (VNZ), according to the Directive 91/676/EEC. By the end of 2010 another VNZ, that of Orounda (Figure 6-17), has been delineated within the Western Mesaoria Groundwater Body. According to the available data, the total agricultural area that is located in vulnerable zones is approximately 200 km^2. Approximately 80% of this land is irrigated with intensive agricultural practices taking place (GSD, 2008).

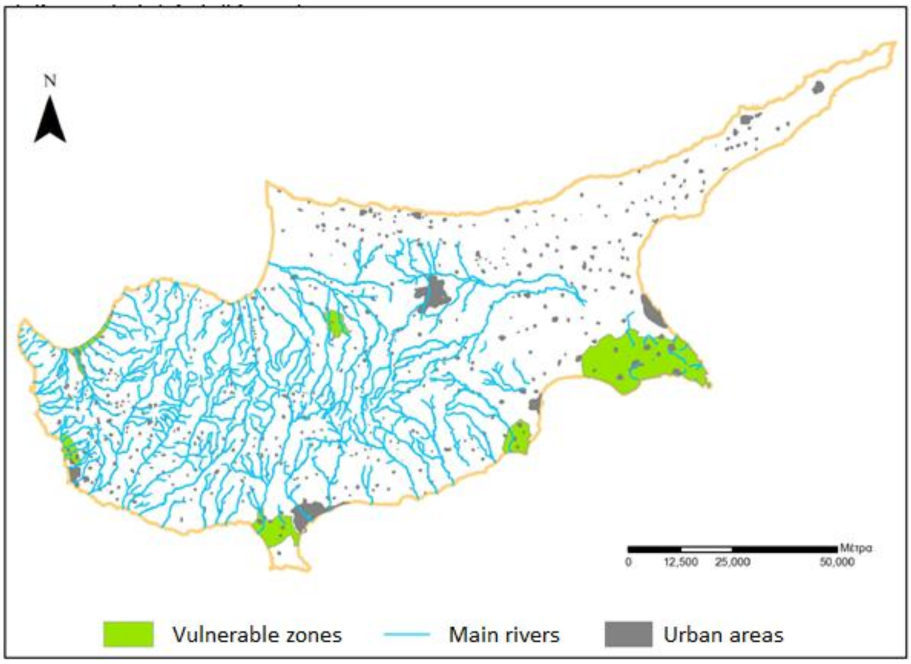


Figure 6-17: Map of Vulnerable Nitrate Zones

Source: MOA

The nitrogen pollution is responsible for the phenomenon of eutrophication. In the following figures (Figure 3-24 and Figure 3-25), the ecological and chemical status of river and lake bodies of Cyprus are depicted in the form of maps, revealing, in general, a good ecological status of river and lake bodies.

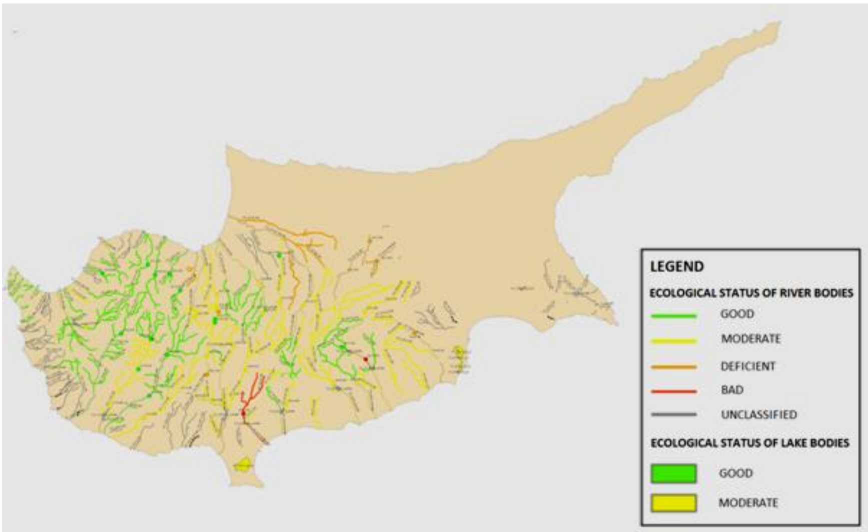


Figure 6-18: Map of the ecological status of river and lake bodies in Cyprus

Source: WDD (1)

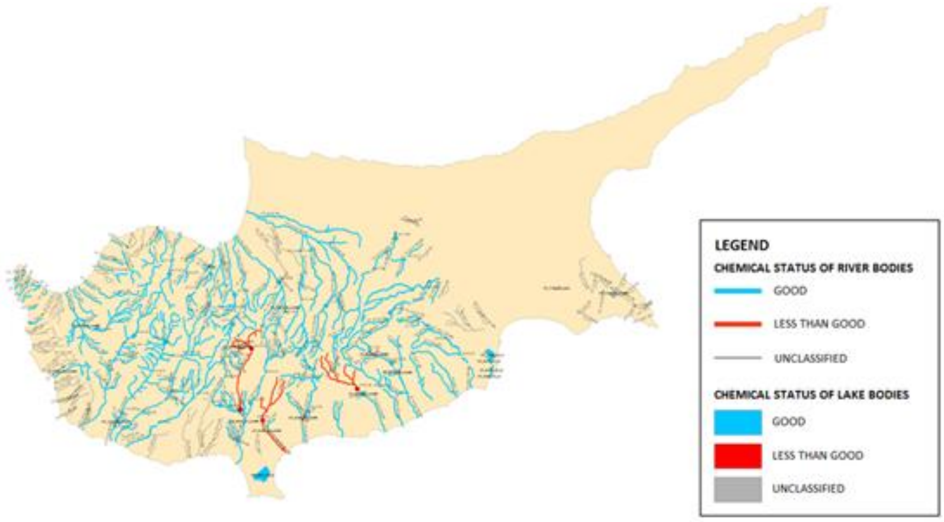


Figure 6-19: Map of the chemical status of river and lake bodies in Cyprus

Source: WDD (2)

Considering the above, the exposure of freshwater biodiversity and quality in Cyprus is considered as **moderate.**

6.4.2.2.2 Assessment of adaptive capacity

The resilience of the organisms of these habitats to climate change refers to their ability to genetically adjust to changing environmental conditions. Nevertheless, most of the times, due to landscape deterioration of this kind of habitats, the phenomena of extinction are inevitable.

The government of Cyprus has taken a series of measures, in order to limit the extent of the phenomena by protecting water resources and inland aquatic species, which constitute the environment of freshwater biodiversity.

The measures for the protection of water resources are the following:

- 13(I)/2004 on the protection and management of water.
- 34/2002 on the nitrogen pollution of waters (based on the European Directive 91/676/EEC).
- 42/2004 on the control of nitrogen polluted waters.
- 41/2004 on the control of water pollution.
- 517/2002 on the control of water pollution.
- 56(I)/2003 on waste management.
- 1/1971 on sewerage systems.
- 108(I)/2004 about sewerage systems.
- 772/2003 about urban wastewater.

- 254/2003 about the nitrogen pollution of waterbodies.
- 106(I)/2002 about the control of the water and soil pollution
- 45/1996 about the control of the water and soil pollution

-In compliance with the Article 6 of the Water Framework Directive (WFD), Cyprus has created a register of all areas lying within its river basin district, which were considered requiring special protection under specific Community legislation for the protection of surface water and groundwater or for the conservation of habitats and species directly depending on water. The register includes all water bodies identified under Article 7 of the WFD and all protected areas covered by Annex IV of the WFD, namely:

vi) Areas designated for the abstraction of water for human consumption in accordance with the Article 7 of the WFD.

vii) Areas designated to protect economically significant aquatic species (areas protected under Freshwater Fish Directive 78/659/EEC and Shellfish Directive 79/923/EEC).

viii) Water bodies designated as recreational waters, including areas designated as bathing waters, in accordance with the Directive 2006/7/EC.

ix) Areas designated as sensitive to nutrient pollution, including areas designated as vulnerable zones under the Nitrates Directive 91/676/EEC -aquifers of Kokkinohoria, Kiti-Pervolia, Akrotiri, Paphos, Poli Chrisohous, the more recently added area of Orounta, (DoA, 2011)- and areas designated as sensitive areas under the Urban Wastewater Treatment Directive 91/271/EEC -the areas 'Polemidhia Storage Reservoir' and the coastal area between Cape Pyla and Paralimni.

x) Areas designated for the protection of habitats or species where maintaining or improving water status is important for their protection, including the sites of the "NATURA 2000" network, established under the Directives 92/43/EEC and 79/409/EEC.

These protected areas include the areas of Natura 2000 network, when the maintenance or improvement of water status is important for their protection, and the areas protected by national legislation. The Natura 2000 network consists of two types of areas, namely the Special Protection Areas (SPAs) for birds as defined in Directive 79/409/EEC, and the Sites of Community Importance (SCIs) as defined in Directive 92/43/EEC. The following table lists the areas of the Natura 2000 network, which include habitats or species directly depending on water (WDD, 2011a – Annex I).

Table 6-14: List of Natura 2000 areas in Cyprus depending on water

Code of protected area	NATURA 2000 code	Type
CY_PR-NP-01	CY2000002	SCI
CY_PR-NP-04	CY2000005	SCI
CY_PR-NP-06	CY2000007	SCI

Code of protected area	NATURA 2000 code	Type
CY_PR-NP-07	CY3000005	SPA/SCI
CY_PR-NP-08	CY3000006	SCI
CY_PR-NP-10	CY4000002	SCI
CY_PR-NP-11	CY4000003	SCI
CY_PR-NP-12	CY4000005	SCI
CY_PR-NP-13	CY4000006	SCI
CY_PR-NP-15	CY4000008	SCI
CY_PR-NP-16	CY4000009	SCI
CY_PR-NP-17	CY4000011	SCI
CY_PR-NP-19	CY5000001	SCI
CY_PR-NP-20	CY5000004	SPA/SCI
CY_PR-NP-22	CY5000006	SCI
CY_PR-NP-23	CY6000002	SPA/SCI
CY_PR-NP-24	CY2000010	SCI
CY_PR-NP-25	CY2000011	SCI
CY_PR-NP-26	CY2000012	SCI
CY_PR-NP-27	CY3000007	SPA
CY_PR-NP-28	CY3000008	SPA
CY_PR-NP-29	CY4000001	SCI
CY_PR-NP-30	CY4000007	SPA/SCI
CY_PR-NP-31	CY4000018	SPA
CY_PR-NP-32	CY4000019	SPA
CY_PR-NP-33	CY4000020	SPA
CY_PR-NP-34	CY4000021	SPA
CY_PR-NP-35	CY4000023	SPA
CY_PR-NP-36	CY5000005	SPA/SCI
CY_PR-NP-37	CY5000008	SPA
CY_PR-NP-38	CY5000009	SPA
CY_PR-NP-39	CY5000010	SPA
CY_PR-NP-40	CY6000007	SPA
CY_PR-NP-41	CY6000008	SPA
CY_PR-NP-42	CY6000010	SPA

Figure 3-30 depicts these Natura 2000 areas on the map of Cyprus. As it can be seen, a considerable number of river, lake and coastal bodies in Cyprus are included in the Natura

2000 network. For more information on these areas, refer to Chapter: Water Resources (Section 3.4.2.2.1 Protected areas).

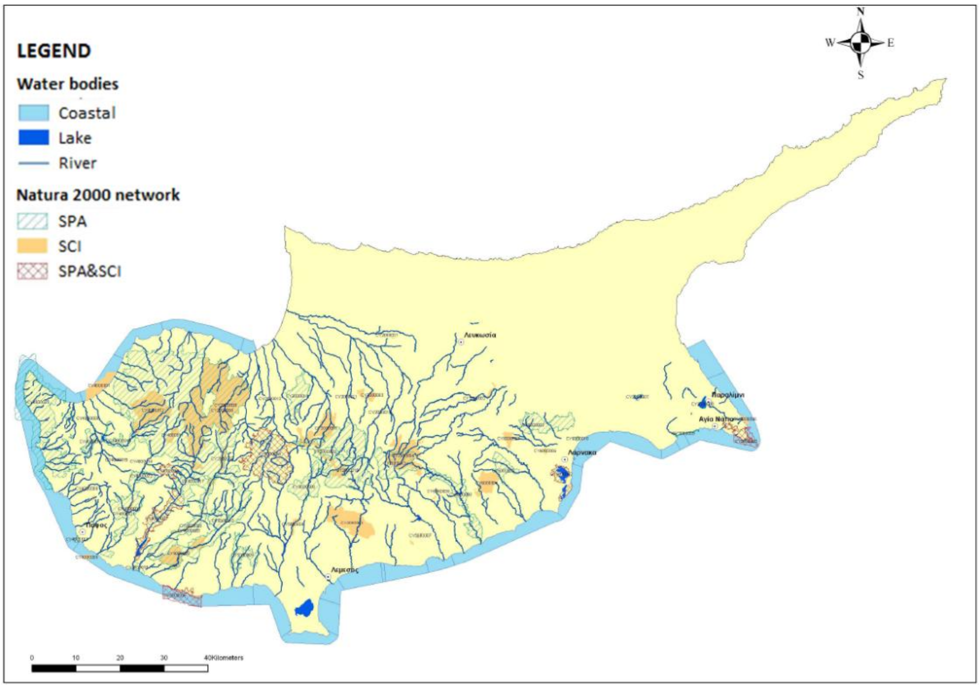


Figure 6-20: Map of Natura 2000 areas in Cyprus depending on water

Apart from the protection of the inland aquatic species, the implementation of these measures is expected to have a central role in improving qualitative water status. However, those measures aim mainly to minimize the human activities causing deterioration of water quality, while other physical parameters such as the deterioration of water quality as a result of decreased flow and increased temperatures are not accounted for. Furthermore, it is recognized that the hydrologic processes are such that it may be many years before protective measures actually lead to improvements in water quality and thus the adaptive capacity is characterized by delayed reversibility. Consequently, the adaptive capacity of Cyprus' freshwater biodiversity and quality to climate changes is considered to be **moderate**.

6.4.3 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of biodiversity to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of biodiversity against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for the biodiversity of Cyprus are summarized in Table 6-15.

Table 6-15: Overall vulnerability assessment of biodiversity in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Distribution of plant species in terrestrial ecosystems	High (5)	High (5)	Limited to Moderate (2)	Moderate (3)
Distribution of animal species in terrestrial ecosystems	High (5)	High (5)	Limited to Moderate (2)	Moderate (3)
Marine biodiversity	Moderate (3)	High to Very high (6)	Moderate (3)	Limited to Moderate (1.2)
Freshwater biodiversity	High to Very high (6)	Moderate (3)	Moderate (3)	Limited to Moderate (1.2)

The main vulnerability of the terrestrial biodiversity towards climate changes appears to be the landscape fragmentations of the island, as species cannot move neither northern nor higher after a certain point. Instead, the main advantage of the marine biodiversity is the ability of migration, which can also be counted as a disadvantage due to the intrusion of harmful invasive alien species.on the other hand, freshwater biodiversity is also threatened due to the landscape fragmentations and the deteriorated freshwater quality especially for groundwater bodies. Considering the above, it is assumed that the first vulnerability priority of the biodiversity in Cyprus to climate changes is the distribution of species in terrestrial ecosystems while the second priority is the biodiversity of aquatic ecosystems.

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7 AGRICULTURE

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Abbreviations and Acronyms

AIO	Agricultural Insurance Organization of Cyprus
CYSTAT	Statistical Service of Cyprus
DERM	Department of Environment and Resource Management
EEA	European Environment Agency
EU	European Union
FAO	Food and Agriculture Organization
GCRIO	U.S. *Global Change Research Information Office*
GDP	Gross Domestic Product
GHG	Greenhouse Gas
ha	hectare
IENICA	Interactive European Network for Industrial Crops and their Applications
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Center
MANRE	Ministry of Agriculture, Natural Resources and Environment of Cyprus
MCM	million cubic meters
NTUA	National Technical University of Athens
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
PICIR	Potsdam Institute for Climate Impact Research
RDP	Rural Development Programme
SMP	Skimmed milk powder
USEPA	United States Environmental Protection Agency
WDD	Water Development Department
WWTP	Waste Water Treatment Plant

7.1 Climate change and agriculture

Agriculture serves for the direct supply of safe, nutritious and affordable food to society and plays an important role in landscape preservation and prevention of desertification (Demetriou, 2005; PICIR, 2005). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007), climatic condition patterns have brought and will bring about numerous changes concerning agricultural activities on a global scale and consequently will influence the world's food supply.

The agricultural sector is highly dependent on climate since temperature, sunlight and water sources are the key factors for plant growth. Although certain impacts of climate change may be beneficial, as for instance prolonged growing seasons and rise of temperatures, there will be severe consequences that can put agricultural activities at significant risk, as well. Shifting weather conditions can cause variations in the sowing and harvest time of various crops. Moreover, extreme weather phenomena, such as heatwaves, droughts or hail can damage arable cultivations and reduce crop yields (Iglesias et al., 2007; IPCC, 2007).

Many studies have been published during the last years taking into account different sets of dynamic factors specific to given regions or countries in order to assess the future direction of the agricultural sector in a changing world governed by complex socio-economic systems. (GCRIO, 1995).

7.2 Baseline situation

Agriculture has always been an economic activity of great importance in the Mediterranean basin. Since early times, the cultivation of fruit, vegetables and olives was a fundamental element of the Mediterranean culture. The agricultural sector was a major source of employment and income for the countries of the region, including Cyprus.

During the period 1960 –1974, concerning the deGclaration of the independence of Cyprus (according to the Zurich-London Treaty), followed by the Turkish invasion in 1974, the primary sector showed a fast-paced development. Small owner-run farms contributed in almost 70% of product exports and employed one third of the island's economically active population. After 1974, the more productive part of the island contributing with 46% of total crop production (79% of citrus, 68% of cereals, 100% of tobacco, 86% of carobs, 65% of green fodder) and 45% of livestock production, was occupied. Consequently, the displacement of the farmers in the less productive part of the island, the shortages of forage and water resources and other difficulties caused by the invasion, resulted in a setback of the broad agricultural sector. Although intensive efforts and government actions were concentrated on land improvement and irrigation so as to come within reach of the pre-1974 levels of production, there are still many problems. These problems are mainly due to the irrational use of water resources, the growing tourism sector which resulted in the shifting of the agricultural labour force to the tourist industry and to a much less extent to the spreading of plant and animal diseases coming from the occupied part of Cyprus (Solsten, 1991; IENICA, 2004; Papamichail, 2009).

In particular, in the 1990's, agriculture's share of the national economy showed a declining trend due to the rapid development of the tertiary sector (tourism, financial and banking services). The Republic of Cyprus entered the European Union (EU) on 1 May 2004 and on January 1, 2008 joined the euro. As it was expected, the accession of Cyprus to the EU had several positive and negative impacts on the socio-economic status of the country. Even though a significant improvement of the National Economy was noted during the last years, the development in the broad agricultural sector was not that satisfactory (Solsten, 1991; IENICA, 2004; Papamichail, 2009).

In the 1960s and after independence, water management has been a difficult challenge because of the inadequate development of the water infrastructure facilities for water supply and irrigation purposes. For this reason, the top priorities of the national government have been focused on increasing available water resources in order to achieve food security and constant supply of high quality water for irrigated agriculture. In this way, water scarcity impacts would not inhibit the socioeconomic progress of this primary sector which was the backbone of the economy with a 20% share in the country's Gross Domestic Product (GDP) (Solsten, 1991; IENICA, 2004; Papamichail, 2009).

At present, agriculture is still considered to be one of the major economic sectors of Cyprus due to the island's favorable climate and its location near its leading market, Western Europe. Additionally, it contributes to the social cohesion, the employment, the protection of the environment, as well as the general welfare of the society (Vakakis and Associates, 2010; Bruggeman et al., 2011a; Savvides et al., 2002).

Following, the main characteristics of the two components of the agricultural sector, i.e. agriculture and livestock, are presented.

7.2.1 Agricultural area and crop production

Based on the CORINE 2006 land cover (see Figure 2-5), the agricultural areas cover almost half of the island's surface (47.8%). From this area, on average 71.5% was covered with permanent and temporary crops during the period 2002-2008 (CYSTAT, 2010).

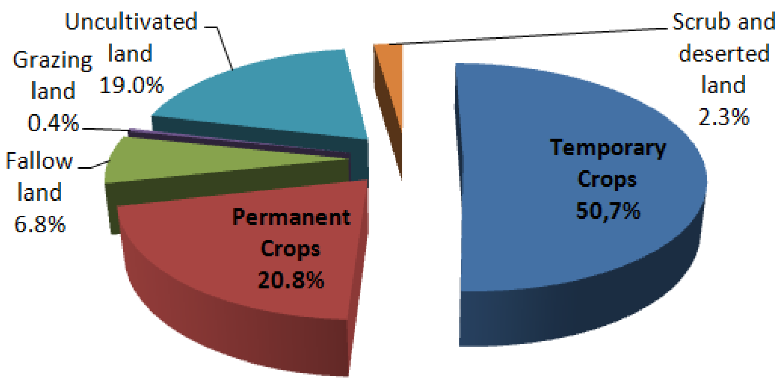


Figure 7-1: Area covered by temporary and permanent crops as a percentage of total crop area, 2002-2008 (CYPADAPT)

Source: CYSTAT, 2010

The most important crops in terms of production value are wheat, potatoes, grapes, citrus, vegetables and olives. Of the area covered with crops during the period 2002-2008, 42.8% was taken up by cereals, 20.5% by fodders, 10.3% by olives and carobs and 8.2% by vineyards (8.2%) while citrus, nuts and fresh fruits cover smaller areas (Figure 7-2) (CYSTAT, 2010).

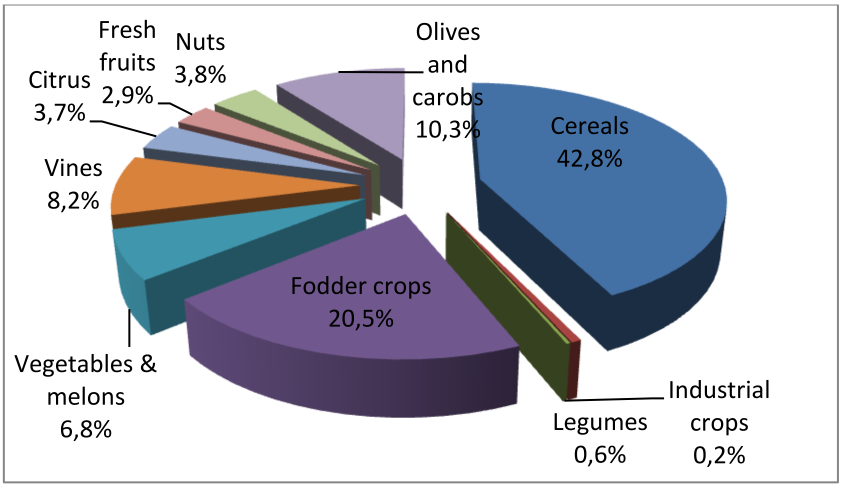


Figure 7-2: Area covered by type of crop as a percent of total crop area, 2002-2008 (CYPADAPT)

Source: CYSTAT, 2010

The average crop production in Cyprus per crop type as a percentage of the total crop production for the period 2003-2008 is presented in the following figure. As it can be seen, approximately 27% of the total crop production comprises of potatoes, 14% of barley, 11.5% of grapes, 9% oranges and 6% grapefruits while other crops have smaller contribution to the total crop production (CYSTAT, 2010).

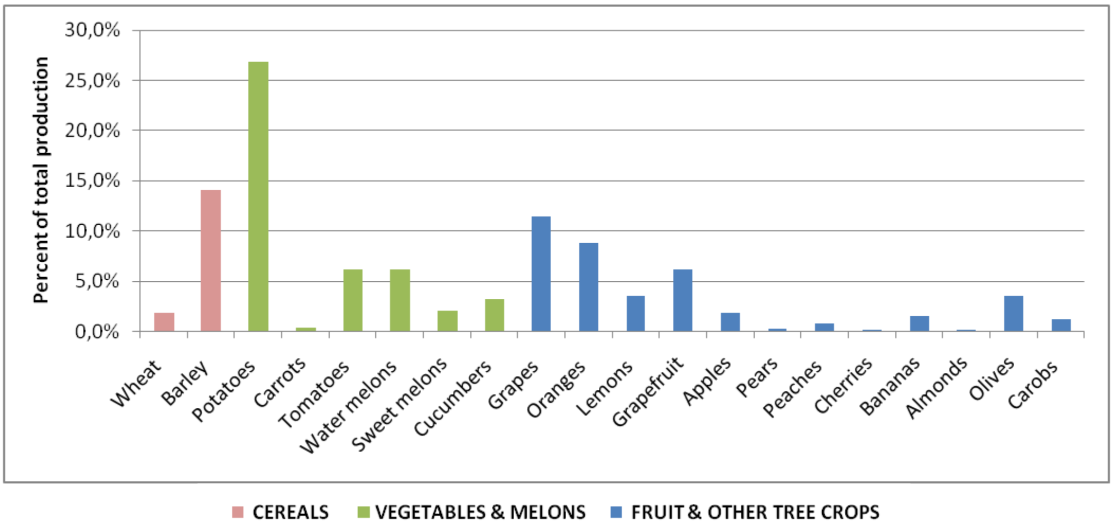


Figure 7-3: Average crop production per type of crop as a percentage of the total crop production in Cyprus, 2003-2008 (CYPADAPT)

Source: CYSTAT, 2010

Agriculture constitutes the dominant water user, accounting for 60% of total water demand in 2011, whereas the domestic share for water was 30% (Figure 7-4).

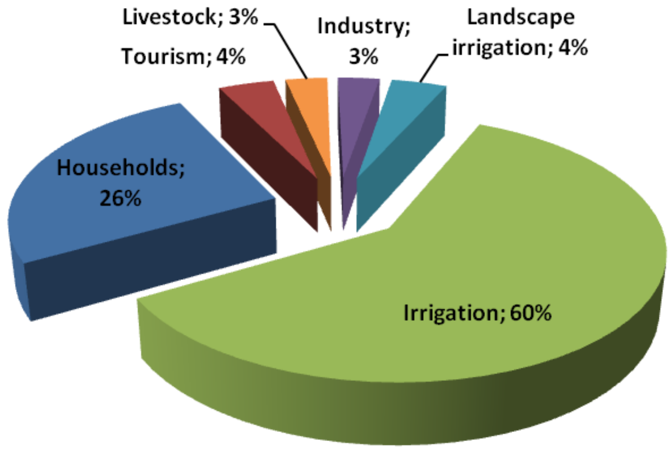


Figure 7-4: Allocation of total water consumption per sector for 2011 (CYPADAPT)

Source: WDD, 2011a

7.2.2 Development of the agricultural sector

Before Cyprus accession in the EU, the income gained from agricultural activities showed increasing trends as farm holders enjoyed higher prices for their products compared to those of the other Member States. After 2004, it exhibited a decrease and reached the levels of 2000, in 2006 (at current prices). It should be noted that in 2007, the income of the farmers was 20% lower (in real terms) than the average of the EU-27. This decline is a result of the decrease of the product prices, the decrease of crop production due to the water scarcity and the rapid increase of the intermediate consumption (input costs).

In general, there is a continuing miniaturization of the Cypriot agricultural sector in terms of the sector's share in the country's GDP and the employment rates, which can be noticed by the data provided by the Statistical Service of Cyprus (CYSTAT, 2010) and are illustrated in Figure 7-5. In specific, the GDP share of the agricultural sector to the total GDP of Cyprus decreased to 2% in 2008 from 5.3% in 1995 and the share of employment in agriculture with respect to the total workforce decreased to 6.3% in 2008, compared to 10.1% in 1995 (CYSTAT, 2010). However, it should be noted that the actual workforce is much higher since part-time farmers are not accounted for, neither their contribution to GDP.

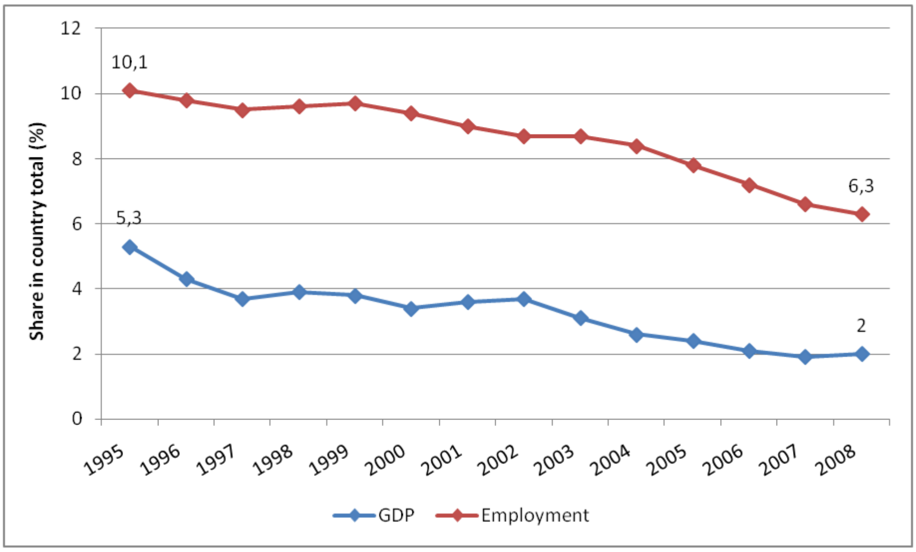


Figure 7-5: Share of agricultural sector in the country's GDP and employment (CYPADAPT)

Source: CYSTAT, 2010

In addition, as it can be seen in Figure 7-6, gross output and value added recorded negative values for several years during the period 1995-2008.

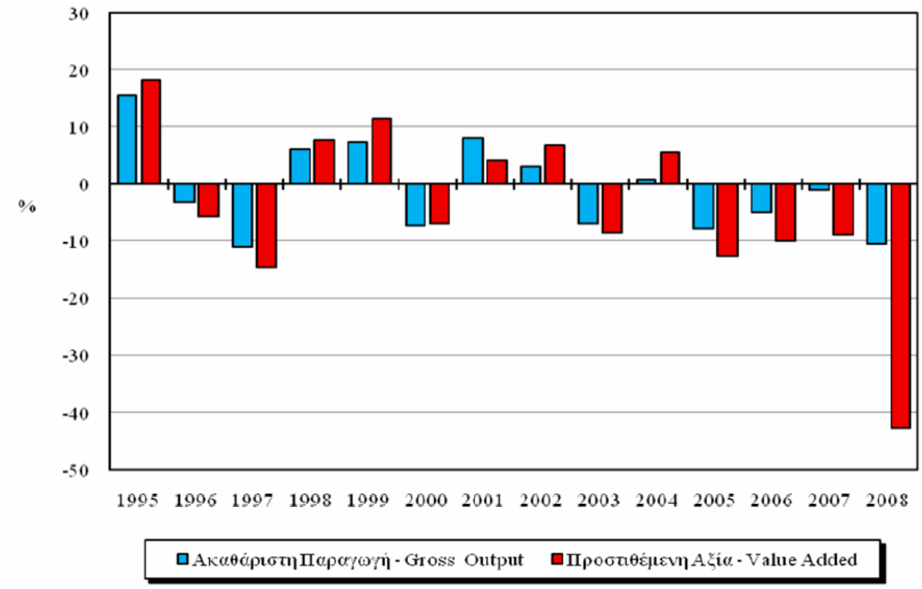


Figure 7-6: Annual real growth of output & added value, 1995-2008

Source: CYSTAT, 2010

Another contributing factor to the rate of development and the productivity of the agricultural sector in Cyprus is the structure of land holdings. Agricultural lands have been highly fragmented due to land inheritance to younger generations. Division of agricultural areas together with highway development, steep slopes and land-use changes from agricultural purposes to urban lots, led to very small plot sizes. In order to ameliorate their practice, farm holders were forced to purchase or rent plots. However, these additional small holdings are usually not adjacent to their main property and this, undoubtedly, reduces efficiency and practicality (Vakakis and Associates, 2010; Deems, 2010). In particular, the average area per agricultural holding was 3.5 ha, while each holding consisted on average of five land parcels (Table 7-1). Almost half of the land was cultivated by their owners (44%), whereas 52% was rented. Moreover, about half of the farm holders and their family members (49%) did not have agriculture as their sole or primary occupation and supplementary employment was needed to survive. A total number of 45,199 agricultural holdings was recorded, including 588 landless livestock farms (CYSTAT, 2006). Data regarding share and amount of employment (days) in relation to the size of the agricultural holdings is presented in Table 7-1. As it can be seen, as the size of the land holding decreases, the employment force in the agriculture sector increases and the average annual employment (days) decreases.

Table 7-1: Employment data in relation to farm holding size, Cyprus

Percentage of employees (%)	Size of agricultural holding (ha)	Average annual employment (days)
50	< 1	48
35	1-5	98
15	> 5	175

Source: Vakakis & Associates, 2010

Furthermore, the vitality of the agricultural sector is significantly affected by the age of the farm holders and consequently by the level of education. The latest survey (Agricultural Statistics 2008) revealed that the average age of farmers was 54 years old, with just 5% of them being under the age of 35 (Bruggeman et al., 2011b).

To this end, it should be noted that all the above-mentioned factors regarding the structure of land-holdings and the characteristics of the work-force related to the agrarian sector could pose limitations when considering practices to improve the adaptive capacity of the sector.

7.2.3 Exports of agricultural products

The principal and most valuable export crops in Cyprus are potatoes, citrus, vegetables and table grapes. As far as the total export activities of the agricultural sector is concerned, the data provided from the Statistical Service of Cyprus (CYSTAT, 2010) for the period 1995-2008, show an increasing trend mainly during the period 2003-2005 while during the whole period there were continuous fluctuations (Figure 7-7). It must be mentioned that, the high prices of local products driven by the decreased quality of soils, the use of solely traditional agricultural practices and the low cooperation schemes of producers have led to decreased crop yields, problems in the distribution and trade of products and have reduced the competitiveness of the sector (Papadavid, 2009; Papamichail, 2009).

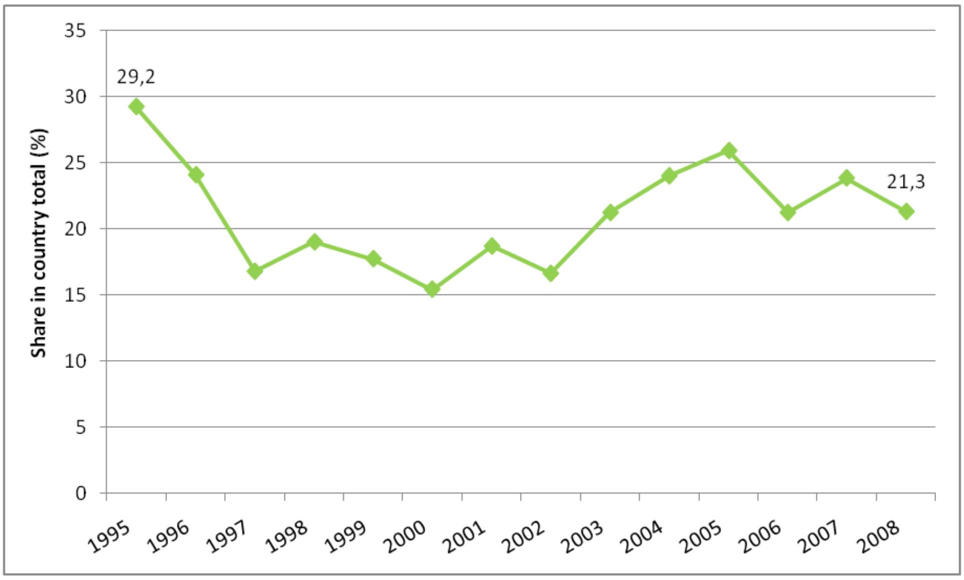


Figure 7-7: Share of agricultural sector in the country's total exports (CYPADAPT)

Source: CYSTAT, 2010

Figure 7-8 presents the trends in exports of the major products during a thirteen-year period, from 1996 to 2008 (CYSTAT, 2010).

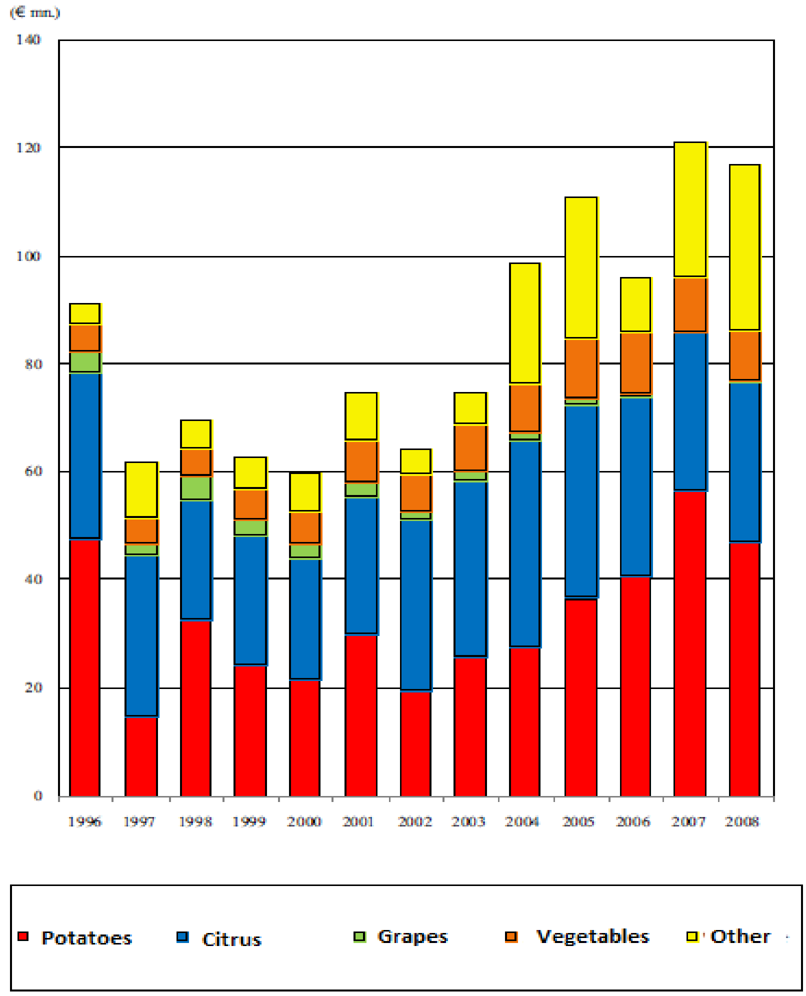


Figure 7-8: Exports of agricultural products in Cyprus, 1996-2008

Source: CYSTAT, 2010

The importance of the European market for the exports of agricultural products in Cyprus is depicted in Table 7-2, as the majority of the agricultural commodities of the island is distributed within its borders. Indicatively, in 2008 the Member States of the EU absorbed 67.1% of agricultural products exports (CYSTAT, 2010).

Table 7-2: Percentage distribution of agricultural exports of Cyprus by geographical regions, 2003-2008

Countries of destination	2003	2004	2005	2006	2007	2008
EU countries	80.0	74.9	71.1	80.4	72.6	67.1
Other European countries	15.5	6.7	7.6	12.5	11.6	11.7
Arab countries	0.7	1.2	2.0	2.4	1.2	2.3
Other countries	3.9	17.2	19.4	4.8	14.5	18.9
TOTAL	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**

Source: CYSTAT, 2010

7.2.4 Water use in irrigation

Agriculture constitutes the dominant water user, accounting for 60% of total water demand in 2011 (Figure 7-4). Government Irrigation Schemes are the main provider of water for irrigation purposes. The amount of available water for irrigation purposes is not stable as it exhibits significant fluctuations from year to year, depending on the weather conditions, the water storage in dams and the state of groundwater aquifers. Furthermore, during drought periods the water supply for irrigation from Government Water Works is restricted in order to meet water demand for the domestic sector first, and thus more groundwater is drilled from private boreholes in order to meet the demand for irrigation. Based on data for the period 2005-2007, the total annual water consumption for irrigation was estimated at 153 million cubic meters from which 31% was surface water provided by Government Water Works, 17% was groundwater provided by Government Water Works while the remaining 52% was groundwater from private boreholes (Vakakis & Associates, 2010).

Cypriot agriculture is irrigated (vegetables, citrus, potatoes, melons, table grapes, deciduous fruit, bananas) or non-irrigated (rain fed) (i.e. cereals, fodders, olives, carobs, wine grapes, almonds) (IENICA, 2004). For the period 2002-2008, 24% of the total crop area was irrigated and 76% was rain-fed (CYSTAT, 2010). The next diagram (Figure 7-9) presents the water demand for irrigation, measured in million cubic meters (MCM) which is distributed to different types of crops. On the graphic bars, a distinction is made between the water amount provided by the Government Irrigation Schemes, as well as by other schemes. As it can be seen in the diagram, the most water-intensive crops are citrus and open-field vegetables.

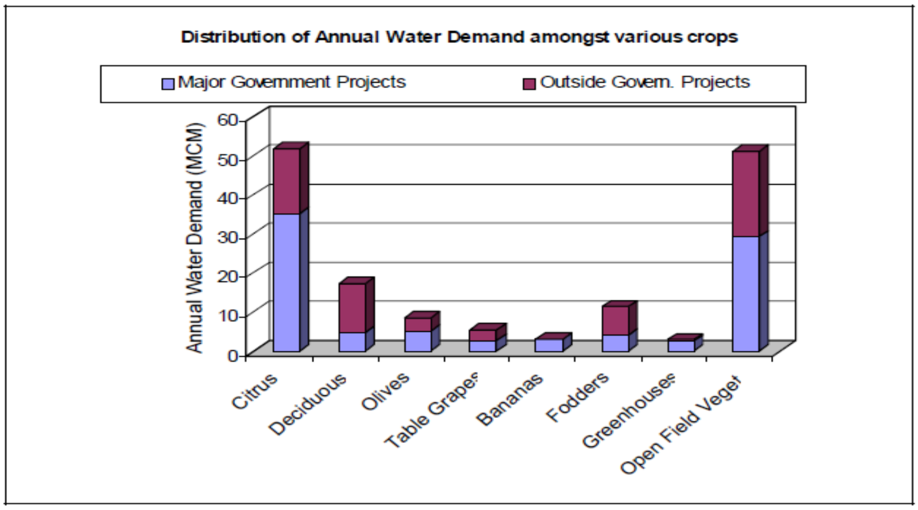


Figure 7-9: Annual water demand data for various crops

Source: WDD – FAO, 2001

The following map (Figure 7-10) depicts a territorial distribution of annual water demand (m^3) for irrigation from Government Irrigation Schemes per crop.

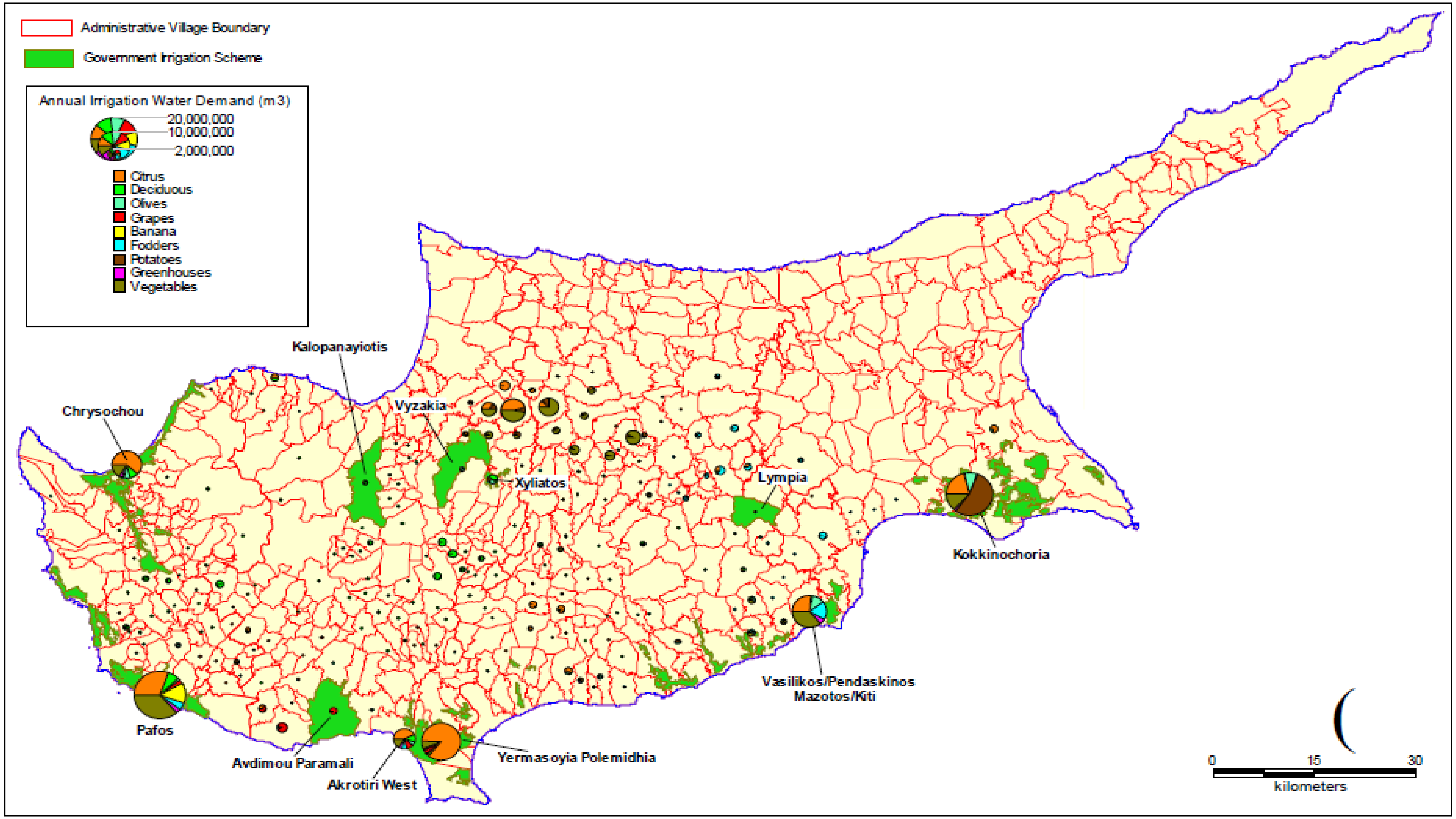


Figure 7-10: Various types of irrigated crops and relevant annual water demand

Source: Chimonidou and Vassiliou, 2006

The water consumption in the animal husbandry sector, is estimated to be 3% of the total water demand in Cyprus (Figure 7-4). The *daily water requirement* of livestock varies significantly among *animal* species (Table 7-3) as the animal's size and growth stage has a strong influence on daily water requirements. Moreover, water consumption intakes can be influenced by several environmental and management factors. Air temperature, relative humidity and the level of animal exertion or production level are some examples. Moreover, the water content of the animal species' diet affects its drinking needs, as for example a type of feed with a relatively high moisture content could decrease the quantity of drinking water required (OMAFRA, 2007).

Table 7-3: Water demand for livestock

Type of unit	Aviculture units	Sheep and Goats Breeding units	Pig Breeding units	Beef cattle breeding units
Daily water needs per animal (L/day)	0.25	8	15	150

Source: WDD, 2011a

7.2.5 Livestock population and production

The second important component of Cypriot agriculture is livestock. Cattle, sheep and goats, pigs and poultry constitute the main subsectors of the animal husbandry industry. During the last years, ostrich farmers have been also established for commercial uses. Their average absolute numbers and percentages in total population during the period 1984-2008, according to data provided by the Statistical Service of Cyprus (CYSTAT, 2010), is depicted in the following figure.

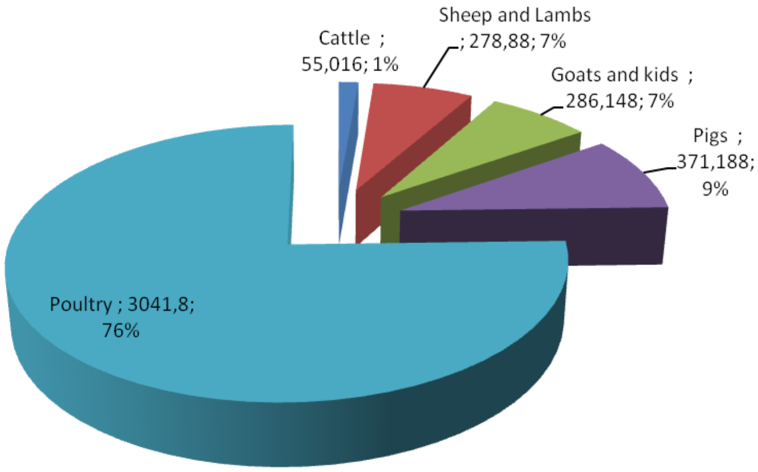


Figure 7-11: Animal population in husbandry (in thousands), average 1984-2008 (CYPADAPT)

Source: CYSTAT, 2010

Meat production during the period 2003-2008 according to CYSTAT (2010) comprised mainly by pork meat (57%) and poultry (31%) while the rest 12% of meat production comprised of beef, kids, goats, lamb, rabbits and mutton (Figure 7-12).

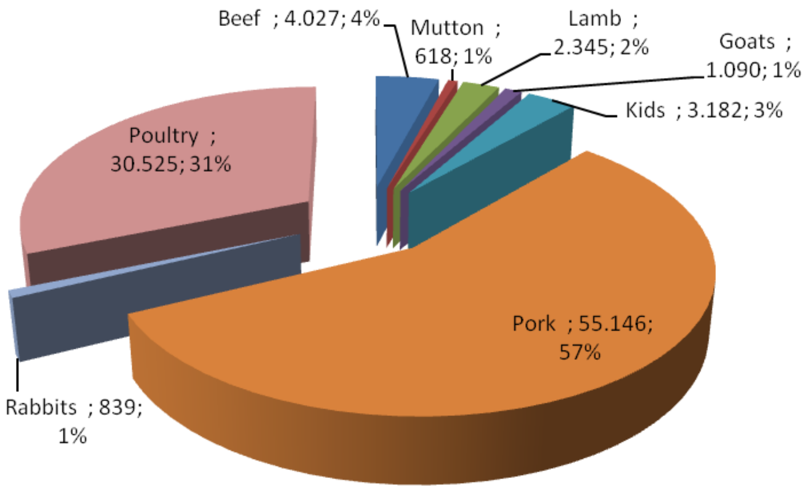


Figure 7-12: Annual meat production (in tons), average 2003-2008 (CYPADAPT)

Source: CYSTAT, 2010

The most important constraints of the livestock sector in Cyprus encompass the insufficient production of animal feed and the dependence on imports. An additional problem is waste handling and the protection of soil and water resources from practices that cause pollution.

7.2.6 Livestock imports and exports

Local needs are fully satisfied regarding fresh pork, poultry meat as well as edible eggs, thus no imports of these commodities are required. In contrast, excess quantities of fresh pork contribute occasionally to the export activities. Moreover, local production of beef /veal, mutton and lamb cover the local needs by 81% and 92% respectively and it is supplemented by imported quantities. The required quantities of pasteurized cow's milk for liquid consumption is completely met with whereas the demand for cheese and other dairy products made from cow's milk as well as sheep and goat's milk is satisfied by 85% and supplemented by imports. Furthermore, the demand for evaporated milk, condensed milk, sweetened or not, whole milk powder, skim milk powder, milk for infants etc. for local use is satisfied by imports, while traditional dairy products are exported.

To conclude, in recent years, a remarkable growth in exports of meat has been witnessed, as shown in Figure 7-13. However, it is unknown whether this trend was merely coincidental or whether long-term opportunities resulted in opening new markets. This remains to be confirmed by the figures in the following years. Taking into account the increasing level of livestock production in Cyprus, if it is supported by the appropriate production and commercial practices, then a potential growth of exports of various meat types will be possible (Vakakis & Associates, 2010).

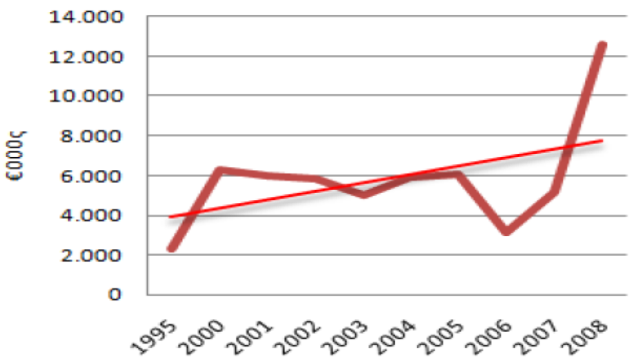


Figure 7-13: Exports of different types of meat, 1995 & 2000-2008

Source: Vakakis & Associates, 2010

7.2.7 Main pressures on agricultural sector in Cyprus

Following the baseline situation presentation of the agrarian sector in Cyprus, the main pressures which define and affect the productivity and competitiveness of the specific sector are highlighted as follows:

a. Small and considerable subdivision of agricultural plots (5 plots and 35 decars per farmer - Census of 2003)
b. Isolation of the population of the rural mountainous areas
c. High average age of farmers (54 years old) which are considered less receptive to the application of new advanced technological practices
d. Reduced income mainly due to limited employment opportunities and plot structure and age of farmers
e. Urbanization leading to abandonment of rural areas, desertification and reduction of natural resources.
f. Declining soil fertility (or nutrient depletion) and,
g. Limited water resources

Other problems associated with agricultural activities refer to the produced wastes and their appropriate handling and disposal (Bruggeman et al., 2011c). All the afore-mentioned factors could be possibly linked to the falling trend in the agricultural sector. However, it should be noted that only factors (f) & (g) are mainly/directly related to climate change, as declining soil fertility is associated with the phenomenon of desertification, soil erosion and nutrient removal through gaseous losses such as denitrification and volatilization, whereas limited water resources are linked to low precipitation and temperature rise projections. In addition to those addressed above, heat stress and sea level rise, along with overpumping of coastal aquifers due to extended water irrigation needs, contribute to the depletion of water and soil quality. Consequently, these pressing parameters lead to reduced crop yields and loss of arable land, and can have also a negative impact on livestock activities (DERM, 2012; EEA, 2008a).

7.3 Impact assessment

Even though the effects of short-term and long-term climate change on the primary sector are generally difficult to be distinguished from non climatic impacts associated with the management of natural resources, there are some basic impacts identified and related to global change (IPCC, 2007; EEA, 2008a). The extent of climate change impacts varies upon different ecosystems, regions and countries. Positive as well as negative impacts take place throughout the world. By way of explanation, the following points are given:

- Scientific research has shown that even a small increase of global temperature will lead to the reduction of agricultural yields and generate higher yield variability in low-latitude areas, worldwide. The frequent occurrence of extreme weather phenomena (such as floods, heat waves and drought) will intensify the negative effects on crop yields.

- Smallholders and subsistence farmers will be severely influenced since they are characterized by low adaptive capacity. Consequently, this fact is expected to result in increased risk of food availability due to socio-economic development.

- Food and forestry trade is projected to increase in response to climate change, with increased food-import dependence of most developing countries (EEA, 2008b; Andreou et al., 2010).

Despite the fact that certain impacts could play a positive role for farming activities in some regions of Europe, mainly concerning northern areas (lengthening of the growing season and increased crop yields because of warmer conditions), the majority of impacts are likely to have a negative influence, result in economic losses, and prevail especially in areas which are already under pressure due to socio-economic and other environmental problems, for instance water scarcity (EEA, 2008b).

According to FAO (2007), the principal climate change impacts on agriculture can be roughly divided into two categories, namely the biophysical impacts and the socio-economic impacts, as shown in Table 7-4.

Table 7-4: Climate change impacts on the agricultural sector

Biophysical impacts	Socio-economic impacts
Physiological effects on crops, pasture, forests and livestock (quantity, quality)	Decline in yields and production

Biophysical impacts	Socio-economic impacts
Changes in land, soil, water resources (quantity, quality)	Reduced marginal GDP from agriculture
Increased weed and pest challenges	Fluctuations in world market prices
Shifts in spatial and temporal distribution of impacts	Changes in geographical distribution of trade regimes
Sea level rise, changes to ocean salinity	Increased number of people at risk of hunger and food insecurity
	Migration and civil unrest

Source: FAO, 2007

The following table summarises the observed and expected climate changes and their implications relevant to the agricultural sector in Cyprus.

Table 7-5: Climate change and impacts related to agricultural sector in Cyprus

Climate change factors	Impacts on agricultural sector
Increased Temperature	– Reduction of crop suitability and productivity – Changes in crop quality – Increased challenges of weeds, crop pests and diseases – Increased water requirements for irrigation – Water scarcity intensification – Water quality deterioration – Intensification of desertification
Decreased Precipitation	– Decreased crop productivity – Intensification of desertification – Decreased soil fertility

Climate change factors	Impacts on agricultural sector
Increase of atmospheric CO_2	– Increased biomass production and increased potential efficiency of physiological water use in crops and weeds – Modified hydrologic balance of soils due to C/N ratio modification – Changed weed ecology with potential for increased weed competition with crops – Increased water use efficiency of some plants and as a result altered competitive interactions of species – Changes in the distribution of animal species
Increase of atmospheric O_3	– Crop yield decrease
Sea level rise	– Loss of arable land in coastal agricultural areas – Soil salinization in coastal agricultural areas – Salinization of groundwater aquifers resulting in low water quality for irrigation
Increased frequency of extreme weather events (heat waves, droughts, hail, floods)	– Crop failure – Damages to crops – Decrease in crop yield – Competition for water between different sectors (irrigation, tourism, domestic etc.) – Damage to grain formation – Increase in pests – Heat stress for animals

Adopted from Iglesias, 2007; Iglesias, 2009a; FAO, 2007; EEA, 2008a

The impacts presented in the table above were grouped in the following impact categories:

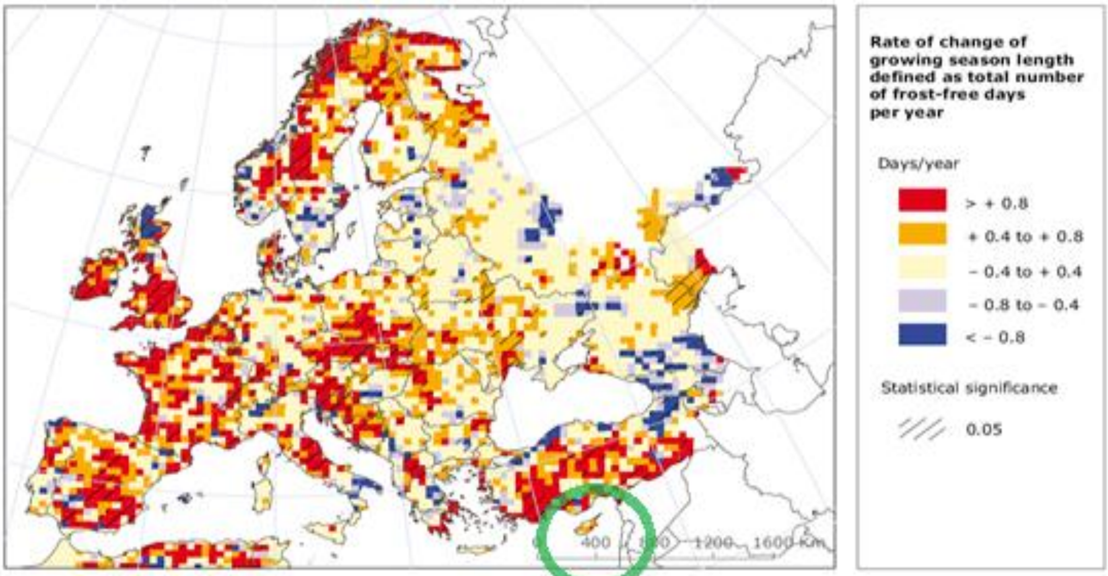
- Crop yield
- Soil fertility
- Pests and diseases
- Damages to crops from extreme weather events
- Livestock productivity
- Costs for livestock catering

These impact categories are going to be further analyzed in the following section.

7.3.1 Crop yield

It is recognized that increases in ambient CO_2 have positive impacts on plant growth. The major effects are on photosynthesis and respiration and thereby on growth (the accumulation of dry matter) (IPCC, 2007). Crop species such as wheat, rice and soybeans are members of the physiological class C3 which respond readily to enhanced CO_2 levels. On the other hand, corn, sorghum, sugarcane and millet belong to the C4 physiological class and tend to be less responsive to elevated concentrations of carbon dioxide even though they possess a greater photosynthetical efficiency. On average, data elaboration confirm that, compared to current atmospheric CO_2 concentrations, crop yields increase at 550 ppm CO_2 in the range of 10-20% for C3 crops and 0-10% for C4 crops (Easterling et al., 2007).

Other positive impacts are associated with the lengthening of the growing season. The length of growing season is regarded as a simple but important indicator of the climate change impacts at local level (EAA, 2008a; Brinkmann, 1979). A prolonged growing season increases crop yields as it strongly assists the optimum use of the available thermal energy, sunlight and water resources and facilitates the presence of new species in certain areas which was limited before because of unfavourable conditions. Nevertheless, a shortening of the growth period could also help prevent harsh summer stress conditions in regions that face drought problems. According to the EEA's assessment report (2008a), it has been proved that the length of the growing season concerning various crop types across the European regions has changed. Growing season length is an event-driven phenomenon as it is influenced by increasing air temperatures, frost days, low rainfall or daylight hours (USEPA, 2012). As it can be seen from Figure 7-2, there is general tendency for lengthening of the growing season especially in the regions in northern latitudes (EAA, 2008a).



Note: The rate of change (number of days per year) of the duration of the growing season (defined as total number of frost-free days per year) as actually recorded during the period 1975–2007.

Source: MARS/STAT database (Genovese, 2004a, 2004b).

Figure 7-14: Rate of change of the duration of the growing season as actually recorded during the period 1975-2007

Source: EAA, 2008a

Scientific data provide evidence that the flowering and maturity phases of several types of plants currently take place two or three weeks earlier than in the past in Europe. Given the increasing trend of temperatures, the aforementioned plant phases will shorten, especially in Western Europe and two or more cropping cycles may take place during the same season. On the other hand, high temperatures may hinder the efficiency of photosynthesis, thus leading to a gradual decrease of the reduction rate of these phenological phases (EEA, 2008a; IPCC, 2007).

However in southern and warmer latitudes, the potential positive impacts on crop yields presented above are not of such a significant magnitude as are the potential negative impacts, which include reduced crop yields due to high temperatures, increased water demand for irrigation and reduced water availability due to periods of prolonged droughts, water scarcity, rainfall decrease and increased competition for water between sectors, which will in turn be much more intense (Behrens et al., 2010).

Increased temperatures may accelerate the rate at which plants release CO_2 in the process of respiration, resulting in less than optimal conditions for net growth. In addition, when the optimal temperature for biological processes is exceeded, crops may be adversely affected with a steep drop in net growth and yield. Another important effect associated with high temperature is the acceleration of physiological development and subsequently of maturation resulting in reduced yields (GCRIO, 1995).

In regions with reduced rainfall and increased temperature, result in increased demand for irrigation water with the subsequent negative impacts for the economy and the environment. Especially for the Mediterranean area, a deteriorating meteorological water deficit has been reported for the last 32 years. Furthermore, the annual number of rainy days is expected to decrease while the risk of summer drought is projected to increase. These areas will experience high competition for water between sectors and users (agriculture, tourism, energy etc.) (EEA, 2008a). The map illustrated in Figure 3-2 provides an estimation of the increase (red-coloured areas) or decrease (blue-coloured areas) of the volume of water needed for irrigation purposes so as not to inhibit crop growth. The rate of change of the *meteorological water balance* is expressed in “m^3 x ha^{-1} x $year^{-1}$”.

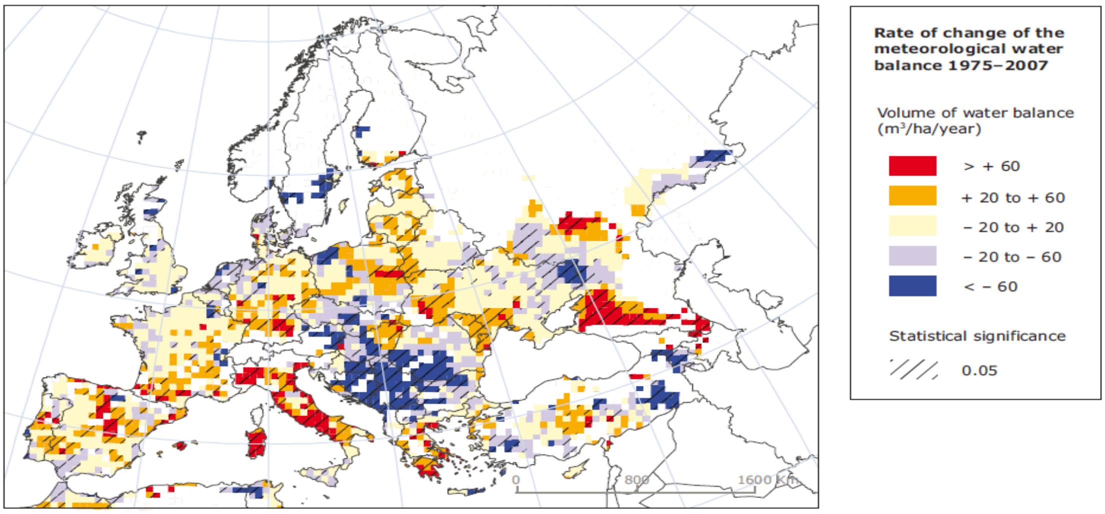


Figure 7-15: Rate of change of the meteorological water balance for the period 1975-2007

Source: EAA, 2008a

The occurrence of moisture stress during flowering, pollination and grain-filling is harmful to most crops. Increased evaporation from the soil and accelerated transpiration in the plants themselves will cause moisture stress. Subsequently, the demand for water for irrigation is projected to rise in a warmer climate, bringing increased competition between agriculture, which is already the largest water consumer in semi-arid regions, and other water users (GCRIO, 1995).

The case of Cyprus

Regarding the effects of elevated CO_2 on plant growth and yield in Cyprus, there are no available relevant research findings. As for the duration of the growing season in Cyprus, a lengthened crop growing season was estimated according to EAA (2008a) with a rate of change of 0.4-0.8 for the biggest part of the island (Figure 7-14).

In general, Cyprus, a region with already warm and dry conditions especially during summer, is likely to experience yield losses due to the increase in temperature and evapotranspiration and the decrease in precipitation, while the projected climate conditions will magnify the already intense water stress circumstances provoking crop failure. According to a recent study conducted by the Agricultural Research Institute of Cyprus, it was concluded that climate variability, high temperatures and low precipitation pose limits to crop production in Cyprus (Bruggeman et al., 2011c).

Moreover, Cyprus has encountered serious drought events and water shortage problems by now with the agricultural sector in Cyprus being the most severely affected and especially the areas that practice irrigated farming for hundreds of years as part of their tradition, as it is the first to receive water cuts during drought years, leading to a significant decrease of the lands covered with annual crops such as vegetables and potatoes.

The following figure shows the crop production in Cyprus during the period 1980-2008, according to data provided by the Statistical Service of Cyprus (CYSTAT, 2010). As it can be observed, there is a general decreasing trend which is however attributed to various other factors apart from climatic parameters, such as the development of the tertiary sector, the assession in the EU and others.

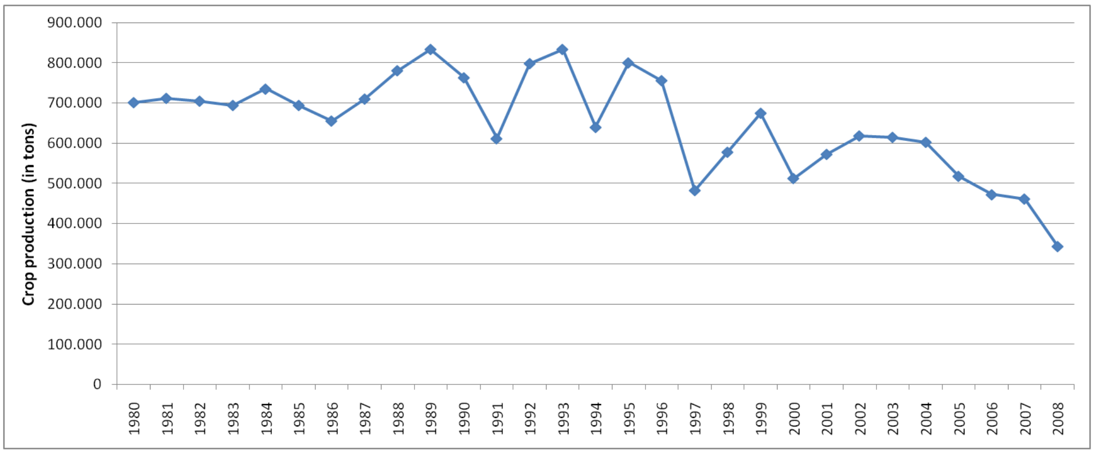


Figure 7-16: Production of main agricultural crops (in tons) in Cyprus, period 1980-2008 (CYPADAPT)

Source: CYSTAT, 2010

7.3.2 Soil fertility

The principal soil aspects that affect soil fertility and are susceptible to climate change are soil biodiversity, organic carbon content, available soil moisture, erosion, salinization and desertification. Rising temperatures lead to loss of organic carbon from soils as the organic content is decomposed and mineralized with accelerated rate. Desertification phenomena cause the conversion of productive lands into non-productive.

Moreover, climate change related factors, as for instance increasing temperatures have a significant influence on variations in timing, intensity and frequency of wildfire events. In case of serious and extended fire events, soil hydrophobicity can occur because of the decrease of hydraulic conductivity and runoff (Moss & Green, 1987). The extended forest fires, undoubtedly affect the cultivation areas and put additional pressure on the agricultural sector (Behrens et al., 2010).

However, it is not only the farmland and crops that suffer. The people that are residing in rural regions and rely on farming for part of their living are considerably affected. This contributes to a multifaceted vulnerability both of the people and of the rural communities (Deems, 2010).

The case of Cyprus

Soil fertility in Cyprus experiences a declining trend. The phenomenon of erosion has affected the arable land in Cyprus and specifically the arable land and the land used for permanent crops. Indicatively it is mentioned that, during the period 1995 – 1999, 56% or 1130 km^2 of agricultural land, was eroded. It must be mentioned that, the available statistical figures denote that soil erosion has actually decreased in absolute values over time, while fluctuations are observed in the share of land that is affected (MANRE, 2007).

Table 7-6: Erosion trends observed on the agricultural land of Cyprus, 1980-1999

Period	Agricultural land		Arable land and land under permanent crops		Meadows and pastures	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
1980 – 1984	1 305	56	1 285	73	20	51
1985 – 1989	1 230	58	1 210	77	20	44
1990 – 1994	1 215	49	1 200	77	15	42
1995 – 1999	1 130	56	1 120	78	10	76

Source: MANRE, 2007

It has been proved by a study assigned to I.A.C.O. Ltd (2007) by the Department of Environment of the Ministry of Agriculture, National Resources and Environment, that climate change can exacerbate desertification phenomena and loss of productive land in Cyprus, by deteriorating the quality of soil with the expansion of droughts. Regarding the fire risk in Cyprus, it is generally considered low but with some high rates of risk located in the forest areas (I.A.CO. Ltd, 2007; Iglesias et al., 2007).

Furthermore, soil salinization poses a threat on Cyprus coastal agricultural land due the reduced water availability for irrigation from Government water supply schemes and the use of water from salinized coastal aquifers for irrigation, as many coastal aquifers have been affected by sea intrusion due to overexploitation (WDD, 2011a).

For a more analytical presentation of climate change impacts on soil resources, on may refer to Section 4 "Soil resources".

7.3.3 Pests and diseases

Pest outbreaks, emergence of new pests and pathogens and an increase in the frequency of diseases, as secondary effects induced by higher temperatures and prolonged growing season will pose extra risk for crop production.

An additional point that should be taken into consideration is that weeds would undergo similar cycle acceleration as cultivated crops and would take advantage of the fertilization of CO_2. Given that the majority of weeds are classified as C3 plants, C3 species of weeds will become more competent and aggressive and may challenge the ability of crops to compete successfully (European Commission, 2007; Karki, 2008).

The primary pathogenic risk due to climate change is the increase of emerging diseases, but its quantification is difficult, since they are affected by extreme weather conditions (Rosenzweig et al., 2005).

<u>The case of Cyprus</u>

There is no available information on pest and weed incidents concerning the agricultural crops and how their trends are correlated to climate change in Cyprus. However, it is very likely that these factors along with the increased occurrence of diseases will exercise an additional pressure on the agricultural sector.

In order extract safe conclusions regarding the climate change impact of pests and diseases on the agriculture sector of Cyprus, the following are considered necessary:

- Data availability on pest/weed and diseases incidents from a long monitoring period
- Correlation with climatic conditions and clear distinction of the effect from other factors influencing their presence (e.g. farming practices)

7.3.4 Damages to crops from extreme weather events

There is evidence that from the beginning of the 21st century, damages to crops due to the occurrence of extreme weather phenomena show an increasing trend (e.g. heat wave of 2003). These extreme events are likely to increase in frequency and magnitude, thus leading to a greater exposure of crop yields. In addition, the magnitude of damage caused to crops depends highly on the timing of the cycle of crops when extreme weather phenomena occur. Modifications concerning farming practices and sensible land use could counteract any resulting issues (EEA, 2008a; GCRIO, 1995; Bruggeman et al., 2011a).

More frequent occurrences of weather extremes, such as dry spells, heat waves and hail incidents will potentially damage agriculture more than changes in the annual average temperature (Behrens et al., 2010).

The case of Cyprus

According to projections concerning the Mediterranean region, a rise of extreme weather events is already experienced and expected to continue in the future. For the case of Cyprus it is indicatively mentioned that, during the period from 1996 to 2005, it was observed that the number of hail events increased over time (Nicolaides et al., 2009).

From Figure 10-10 which presents the amounts of compensations provided to farmers during the period 1987-2007 for crop losses attributed to extreme weather events, based on data provided by the Agricultural Insurance Organization of Cyprus (AIO, 2008a), a slight increase in the amounts of compensations paid is observed which could imply an increase in the frequency and intensity of extreme weather events.

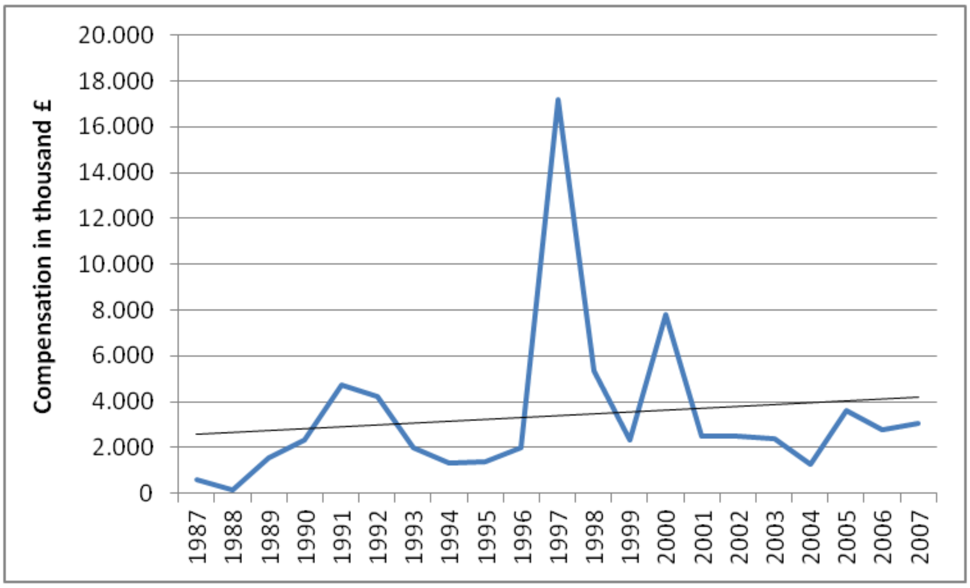


Figure 7-17: Compensation provided to farmers for damages caused to crops due extreme weather events in Cyprus (1987-2007) (CYPADAPT)

Source: AIO, 2008a

From Figure 10-9, which presents the amounts of compensations provided to farmers during the period 1978-2007 for each extreme weather event causing crop losses (AIO, 2008b), an increase in the amounts of compensation paid is observed, especially for crop damages caused by hail events.

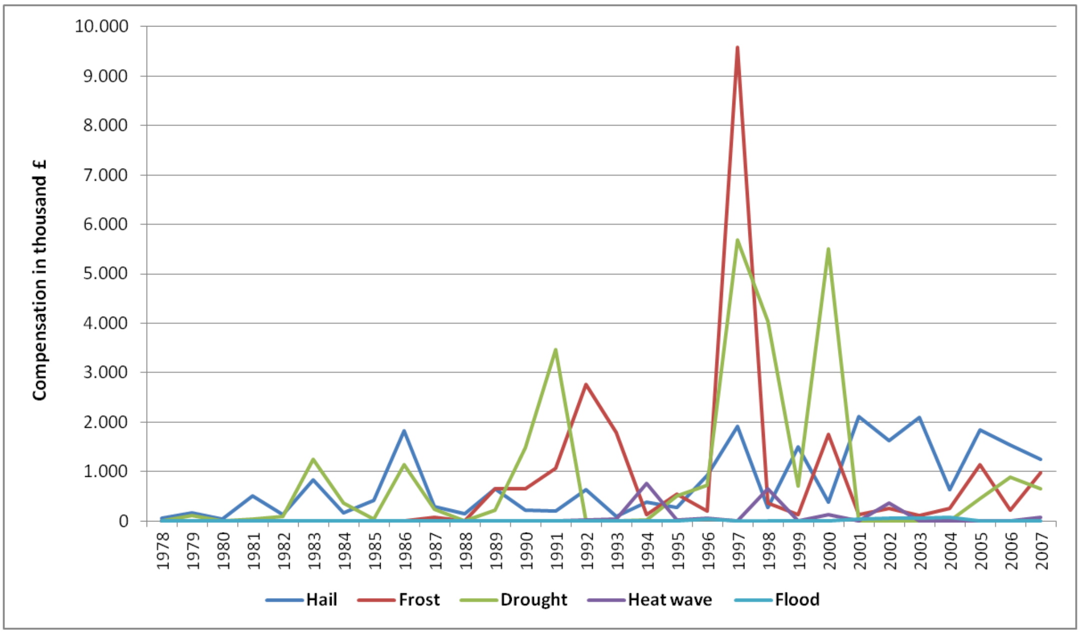


Figure 7-18: Compensation provided to farmers for damages caused to crops due extreme weather events in Cyprus, per event (1978-2007) (CYPADAPT)

Source: AIO, 2008b

7.3.5 Livestock productivity

Extended warm periods and heat waves are likely to adversely affect the livestock sector due to diseases outbreaks and heat stress suffered by animals which may result in reduction of the feed intake rate, the decline of growth and conception rates as well as in reduction of the productivity rates and can ultimately threat livestock life and lead to the extinction of species (Rowlinson, 2008).

In addition, warmer and drier climate conditions may reduce forage production resulting in shortage of animal feed which could modify animal diets and reduce growth and reproduction rates. Higher temperatures and changes in precipitation patterns may also cause the spreading of animal diseases, thus putting additional constraints to livestock productivity (IFAD, 2009).

<u>The case of Cyprus</u>

The most important constraints of the livestock sector in Cyprus encompass the insufficient production of animal feed, as the limited water resources in Cyprus have also a negative effect on livestock feed production systems, as well as on fodder yields.

In the following figure, the meat and milk production in Cyprus during the period 1980-2008 is illustrated, based on the data provided by the Statistical Service of Cyprus (CYSTAT, 2010). As it can be seen, both meat and milk production follow a general increasing trend, while the years 2004-2007 are marked with a sudden reduction of production. However, in absence of sufficient data, this cannot be associated with climate changes as there may be a number of other factors responsible for this reduction, such as market prices.

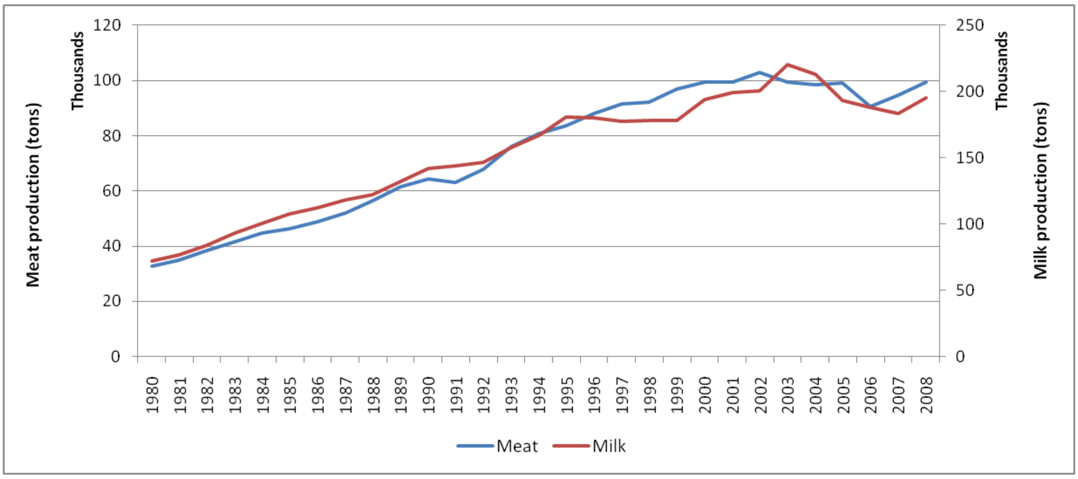


Figure 7-19 Meat and milk production in Cyprus, 1980-2008 (CYPADAPT)

Source: CYSTAT, 2010

In order extract safe conclusions regarding the climate change impacts on livestock productivity in Cyprus, the following are considered necessary:

- Data availability on non-climatic factors affecting livestock production
- Correlation of livestock production with climatic conditions and clear distinction of the effect from other influential factors (e.g. market prices)

7.3.6 Costs for livestock catering

Reduced yields of forage crops due to increased temperatures and decreased rainfall in summer, increase costs for farmers for providing other sources of feeding. In addition, increased demand for irrigation of forage crops will further increase costs for farmers.

Increased risk for heat stress and unproductive grazing land during the summer months as well as the increase in extreme weather events may lead to increased housing requirements. Increased mechanical ventilation of both housing and transportation for livestock for in order to reduce the risk of thermal discomfort in animals and the risk of spreading of diseases is also expected to increase the cost for livestock catering.

However, the risk associated with these problems is regarded as low (Iglesias et al., 2007).

<u>The case of Cyprus</u>

The livestock sector in Cyprus is constrained by the dependence on imports due to the insufficient production of animal feed. However, there is no sufficient information available in order to estimate the climate change impacts on the costs for livestock catering in Cyprus.

In order extract safe conclusions regarding the climate change impact on the costs for livestock catering in Cyprus, the following are considered necessary:

- Data availability on expenses made by farmers for importing animal feed, housing, ventilation etc.
- Correlation with climatic conditions and clear distinction of the effect from other factors

7.4 Vulnerability assessment

In this section, the vulnerability of the agricultural sector to climate change impacts is assessed in terms of its sensitivity, exposure and adaptive capacity, based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which agriculture is affected by climate changes, exposure is the degree to which agriculture is exposed to climate changes and their impacts while the adaptive capacity is defined by the ability of agriculture to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector. The indicators used for the assessment of sensitivity, exposure and adaptive capacity of the agricultural sector of Cyprus to climate change impacts are summarized in Table 7-7.

Table 7-7: Indicators used for the vulnerability assessment of climate change impacts on the agricultural sector of Cyprus

Vulnerability Variable	Selected indicators
Crop yield	
Sensitivity	- Percentage of C3 and C4 plants - Reduction in crop production during dry years - Sensitivity of rainfed and irrigated crops to reduced precipitation - Water allocation for irrigation between permanent and temporary irrigated crops - Sensitivity of mountain and coastal crops
Exposure	- Areas covered with rainfed and irrigated crops - Contribution of rainfed and irrigated crops to the total crop production - Areas covered with permanent and temporary irrigated crops - Contribution of permanent and temporary irrigated crops to the total crop production - Percentage of unmet water demand for irrigation (water cuts) - Areas covered with mountain and coastal crops
Adaptive capacity	- Increase water availability from Government Water Works (increase storage capacity, use of desalinated water, treated effluent from WTTPs) - Increase water availability by applying on-farm practices (collection of rainwater) - Increase water use efficiency in irrigation (redistribution of irrigated land, use of advanced irrigation systems, irrigation scheduling) - Reduce run-off - Use less water intensive crops - Increase crop productivity (crop rotation, fertilization, use of crops more resistant to hot and dry climates)
Soil fertility	

Vulnerability Variable	Selected indicators
Sensitivity	- Sensitivity of arable land to erosion - Sensitivity of arable land to desertification - Sensitivity of coastal agricultural land to soil salinization
Exposure	- Percentage of arable land subject to erosion - Salinization of coastal aquifers - Use of low quality (saline) groundwater for irrigation - Areas covered with coastal crops - Percentage of crops located in areas critical to desertification
Adaptive capacity	- Substitution of the use of chemical products in agriculture (mechanical destruction of weeds, use of natural means for pest management, organic production) - Guidance and technical support to farmers regarding salinity and infiltration problems
Pests and diseases	
Sensitivity	- Plant species in competition with the agricultural crops* - Pest patterns* - Plant diseases favoured by the cypriot climatic conditions* - Crops sensitive to diseases *
Exposure	- Number of pest outbreaks * - Areas covered by weeds * - Recorded incidents of diseases *
Adaptive capacity	- Promotion of indigenous and locally adapted plants and animals - Development of an integrated pest management strategy - Application of crop rotation - Resistance enhancement of existing plants and animals against pests and diseases - Use of pesticides
Damages to crops due to extreme weather events	
Sensitivity	- Crops affected by extreme climatic events - Extreme climatic events affecting crops in Cyprus - Sensitivity of crops to each extreme weather event
Exposure	- Frequency of extreme climatic events causing damages to crops in Cyprus
Adaptive capacity	- Increase water availability for irrigation and reduce run-off - Installation of windbreaks - Establishment of woodlands - Covering crops with nets for the protection from hail
Livestock productivity	

Vulnerability Variable	Selected indicators
Sensitivity	- Animal species sensitive to increased temperatures and heat waves and percentage of their population over the total animal population in husbandry * - Sensitivity of conception and production rates during extended warm periods *
Exposure	- Frequency of extended warm periods in Cyprus * - Reduction of the available animal feed * - Incidents of diseases outbreaks and heat stress on livestock * - Percentage of livestock with no housing and ventilation facilities *
Adaptive capacity	- Improve outdoor conditions (plantation of hedgerows of forest trees for increasing shade and decreasing wind force) - Improve indoor conditions (use of thermostats, cooling and ventilation systems within animal housing areas) - Establishment of a gene bank for animal species to protect genetic diversity - Improved breeding and management methods - Veterinary services for animal disease control and treatment - Enhancing local production of animal feed - Enhancing management skills of farmers
Costs for livestock catering	
Sensitivity	- Increase in costs for livestock catering during extended warm periods in Cyprus *
Exposure	- Deficit in local animal feed production * - Excess costs for importing animal feed, for providing housing, ventilation *
Adaptive capacity	- Financial support provided by the Rural Development Programme of Cyprus for improving outdoor and indoor conditions for livestock

**There were no data available regarding this indicator*

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability is assessed for each of the impact categories presented in Section 3:

1. Crop yield
2. Soil fertility
3. Pests and diseases
4. Damages to crops from extreme weather events
5. Livestock productivity
6. Costs for livestock catering

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability. In case additional data are provided by the competent authorities of Cyprus, the vulnerability of the sector could be re-assessed.

7.4.1 Crop yield

7.4.1.1 Assessment of sensitivity and exposure

In general, the plants which are quite sensitive to increased concentrations of CO_2 belong to the C3 physiological class. These plants account for 85-95% of all plant species. Corn, sorghum, sugarcane and millet belong to the C4 class which is less sensitive to elevated concentrations of carbon dioxide even though they possess a greater photosynthetical efficiency. On average, it is estimated that, compared to current atmospheric CO_2 concentrations, crop yields increase at 550 ppm CO_2 in the range of 10-20% for C3 crops and 0-10% for C4 crops (Easterling et al., 2007).

However, C3 plants are more sensitive to hot and dry conditions compared to C4 plants. C3 plants present accelerated rates of CO_2 release during the process of respiration, resulting in less photosynthetic efficiency and optimal conditions for net growth. On the other hand, the process of photosynthesis in C4 plants C4 and CAM plants is faster than C3 plants under high light intensity and high temperatures and they present better water use efficiency adapted to arid conditions.

Considering the above, it is assumed that for hot and dry conditions as in Cyprus, the positive effect of increased CO_2 concentrations on the yield of C3 plants is counterbalanced by their decreased photosynthetic and water use efficiency in such climates.

In order to assess the sensitivity of crop production to precipitation, data on annual crop production from the Statistical Service of Cyprus (CYSTAT, 2010) were used in conjunction with data on precipitation provided by the Meteorological Service of Cyprus (MSC, 2012), for the period 1987/88-2007/2008. The data - illustrated also in Figure 7-20 - show that crop production is highly sensitive to precipitation as both rainfed and irrigated crops fluctuate over time in parallel to the fluctuations in precipitation, with rainfed crops being a little more sensitive than irrigated crops. Especially for the year 2008, a decline of 10.5 % in the gross output production was reported as a consequence of adverse weather conditions (Figure 7-6). The lack of water caused an extensive reduction of crop production, with rainfed crops such as cereals, straw and green fodder being mostly affected, presenting a reduction of 90%, 85% and 87.6% respectively. During the period 2002-2008 in Cyprus, rainfed crops covered on average 82% of the total crop area and irrigated crops the rest 18% on average while their contribution to the total crop production was 32% and 68% respectively (CYSTAT, 2010). Considering the percentage of rainfed crops in the total crop production, the exposure of crop yields regarding this indicator, is characterized as moderate.

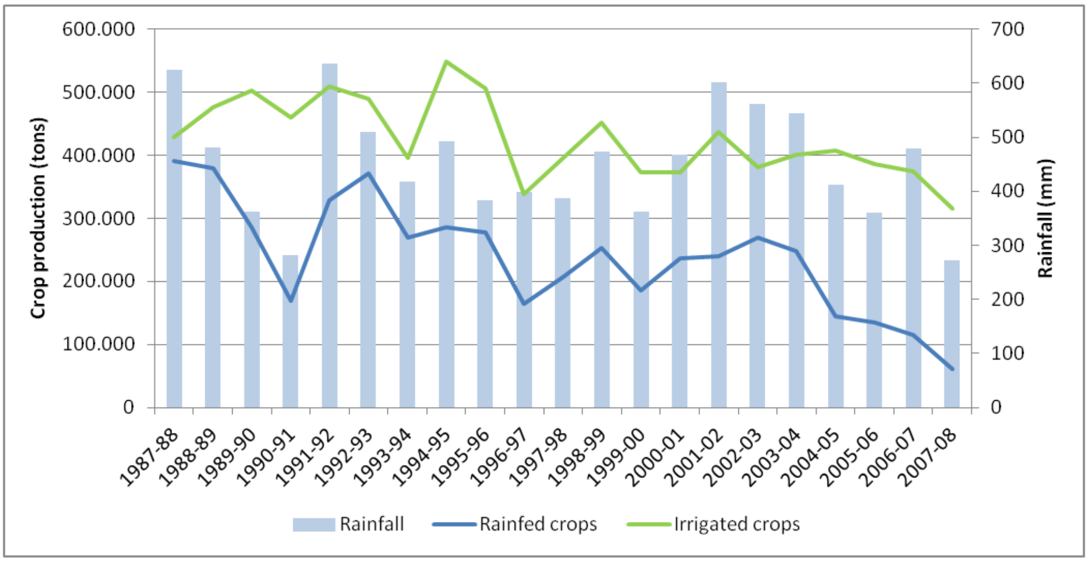


Figure 7-20: Rainfed and irrigated crop production and precipitation during the period 1987/88-2007/8 (CYPADAPT)

Source: CYSTAT, 2010; MSC, 2012

In addition, the sensitivity of crop production to water availability especially for irrigated crops depends on the water allocation policy of Cyprus under drought conditions (water rationing) and the prioritization of water uses. While the first priority is to satisfy the water demand of the domestic sector, the second priority is to maintain supplies to permanent crops at 80% of the recommended application levels and the last priority is to satisfy water requirements for temporary (vegetable) crops (WDD, 2011b). In general, water cuts in irrigation from the South Water Conveyor System during the period 2000-2010 ranged from 10% to 90% with the exception of 2004 where the water cuts were equal to zero (WDD, 2011b). Consequently, the yields of irrigated temporary crops are more sensitive to water availability under drought conditions. During the period 2002-2008 in Cyprus, irrigated temporary crops (vegetables) covered on average 28% of the total crop area and produced 44% of the total production (CYSTAT, 2010). Considering the percentage of irrigated temporary crops in the total crop production as well as the restrictions imposed to irrigation during droughts, the exposure of crop yields regarding this indicator, is characterized as high to very high.

This is also shown in the study of Bruggeman et al. (2011c), which concluded that temporary crop production presents a fluctuation over time, following a similar trend to that of precipitation, i.e., in dry years the production decreases and vice versa while on the other hand, production of permanent crops presented a steady decrease with minor fluctuations over the past 29 years (see Figure 7-21).

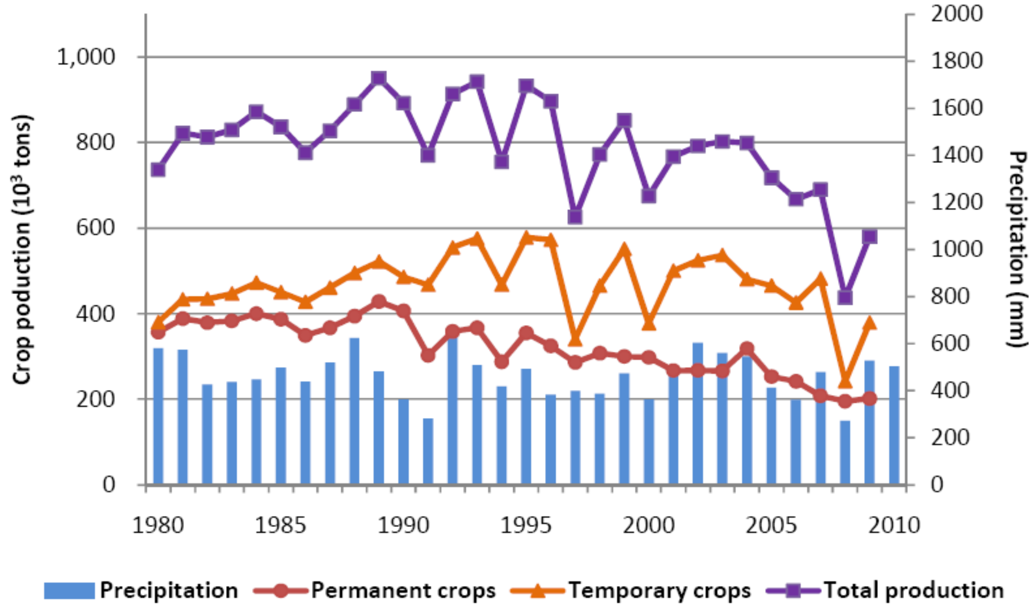


Figure 7-21: Crop production and precipitation during 1980/81-2009/10

Source: Bruggeman et al., 2011c

In particular during the period 1980/1 - 2008/9, the area of temporary crops peaked after a sequence of three wet seasons in 2005 (101.9×10^3 ha) and decreased sharply during the 2008 drought year (70.9×10^3 ha) (see Figure 7-22). Approximately, 50% of the temporary area is used for the production of cereals and 25% for fodder crops. It is interesting to mention that both groups are inversely correlated over time, e.g. when cereals increased, fodder crops decreased. This fluctuation is attributed to the fact that most crops included in these groups are rain-fed. During wet years, more area is harvested for cereals and less for fodder crops and vice versa. The remaining temporary crops are mainly irrigated crops and have steadily decreased over time. Potatoes, for instance, decreased from 9.9×10^3 ha in 1995 to 5.4×10^3 ha in 2009 (Bruggeman et al., 2011c).

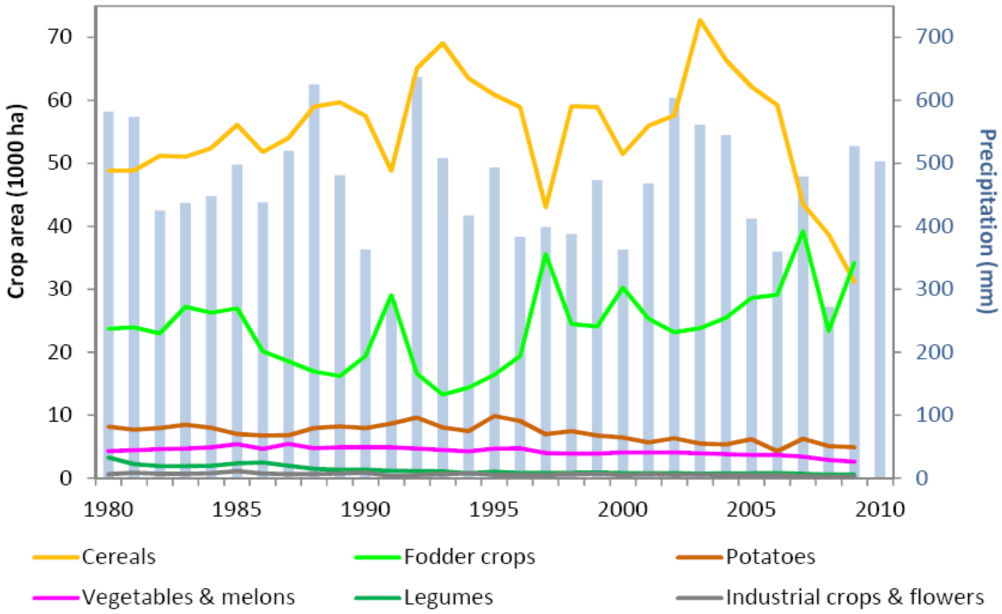


Figure 7-22: Harvested areas of temporary crop groups (1980-2009) and average seasonal precipitation

Source: Bruggeman et al., 2011b

Moreover, the harvested permanent crop area fell by almost 40% (from 62.2×10^3 ha in 1980 to 38.4×10^3 ha in 2009). The main loss was reported for the vine growing area, which was reduced from 34.3 to 8.3×10^3 ha, as well as for the holdings planted with nut trees, which decreased from 13.3 to 5.3×10^3 ha, whereas the olive trees area increased from 5.7 to 12.0×10^3 ha (see Figure 7-23). However, it should be mentioned that the reduced production of grapes, for example, is not attributed to reduced crop yields, as during the year 2008 farmers received subsidies in order to replace certain local indigenous grape varieties with other local or foreign ones with higher commercial value and more competitive features. It is true that the recommended foreign varieties for replanting can often have trouble adjusting to the climatic conditions of Cyprus and thus lower yields are achieved. In spite of this, they are preferred for commercial purposes (Bruggeman et al., 2011c).

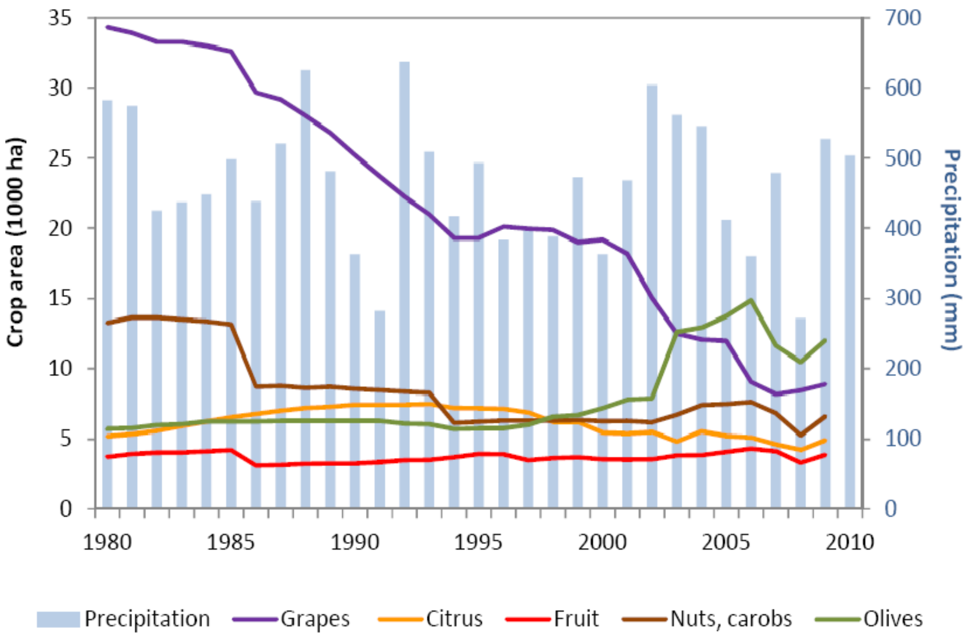


Figure 7-23: Harvested areas of permanent crop groups (1980-2009) and average seasonal precipitation

Source: Bruggeman et al., 2011b

The study also concluded that the loss in irrigated production is mainly due to the reduction in irrigation water supply, whereas the loss in rain-fed production is both due to climate change and an overall decrease in agricultural land use (Bruggeman et al., 2011c).

Crop location is also linked with reduced crop yields under climate changes, as for example, groundwater resources are limited in the steepest areas of the mountainous regions, fact which impedes the development of government irrigation schemes and irrigation practices. On the other hand, coastal regions have less precipitation than mountainous regions, however, government irrigation schemes are more often found in the plains and coastal areas. In addition, crop yields in coastal areas are adversely affected due to the irrigation of crops with low quality (saline) groundwater, as a result of water scarcity and limited water availability for irrigation, overexploitation of groundwater resources and the decline of groundwater tables which in turn caused sea intrusion and salinization of most coastal aquifers. With climate changes, the aforementioned effects on mountain and coastal crops are expected to be exacerbated, thus making them highly sensitive to climate changes. However, as it can be seen from Figure 7-24 which shows the geographical distribution of crops in Cyprus, mountain crops are limited while coastal crops are mainly located in the eastern coast of the island. Thus, their exposure is considered moderate.

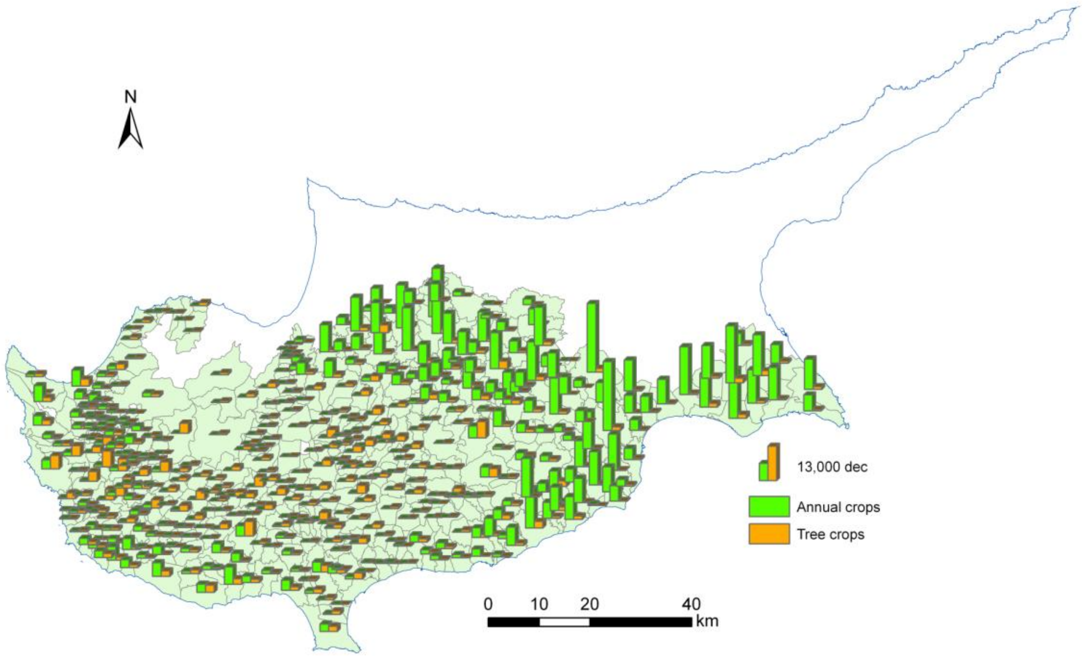


Figure 7-24: Distribution of the annual and tree crops

Source: Bruggeman et al., 2011d

Taking into consideration all the aforementioned indicators used for estimating the magnitude of the impact of climate changes on crop yields, the sensitivity to this impact is characterized as **very high** and the exposure as **high**.

7.4.1.2 Assessment of adaptive capacity

The practices applied in Cyprus in order to reduce the impact of reduced crop yields are mainly associated with measures for (a) increasing water availability for irrigation, (b) reducing water demand for irrigation and (c) increasing crop productivity.

(a) Increase water availability for irrigation

The increase in water availability for irrigation is achieved through Government Water Works which aim in increasing water availability for all uses thus resulting in more water available for irrigation as well as through on-farm practices.

i) <u>Increase water availability from Government Water Works</u>

Increase water storage capacity by constructing numerous reservoirs, utilization of non conventional water resources such as such as desalinated water, treated water from Waste Water Treatment Plants (WTTPs). By increasing water availability with the use of desalinated water, drinking water requirements are satisfied thus allowing for more freshwater resources to be used for irrigation. Treated wastewater is used in agriculture for the irrigation of crops (excl. edible raw vegetables). However, the water demand of the agricultural sector is still not fully met due to the large amounts of water required (60% of total water demand in Cyprus) and the water scarcity characterizing the island.

ii) Increase water availability by applying on-farm practices

Farmers may explore other ways to supplement water supply and secure sufficient and continuous crop irrigation. This may be achieved by on-farm rainwater harvesting and establishing small-scale water reservoirs on farmland while ensuring the sustainable use of water resources and avoiding groundwater overexploitation. However, these practices do not find wide application in Cyprus. In order to promote such initiatives on farm level, the Rural Development Programme 2007-2013 of Cyprus, is providing incentives to farmers for the implementation of these measures.

(b) Reduce water demand for irrigation

The reduction in water demand for irrigation is achieved through (i) increasing water use efficiency in irrigation, (ii) reducing run-off and (iii) using less water intensive crops.

i) Increase water use efficiency in irrigation

- *Redistribution of irrigated land*. Land redistribution constitutes another measure which is directly linked with the decrease in water demand, through the reduction in the fragmentation of agricultural holdings, the opportunity for scale economies in irrigation works and the achievement of significant water savings. Since 1969, 62 out of 73 submitted redistribution plans referred in irrigated land and 3 in mixed, irrigated and rainfed land. In addition, another 12 plans are in progress and 27 under examination, both referring in irrigated land (WDD, 2011b).

- *Use of advanced irrigation systems*. A Water Use Improvement Project has been implemented by the Department of Agriculture since 1965. According to this project the government provided farmers with technical and financial assistance to turn from traditional surface irrigation methods to modern irrigation methods. Due to the relatively high installation costs, the drip method was initially used for irrigation of high value crops, such as greenhouse vegetables and flowers. At a later stage, the installation cost was reduced, and the use of drippers, mini sprinklers and low capacity sprinklers was expanded for irrigating trees and field vegetables. As a result, during the last decades farmers have extensively adopted modern irrigation systems. The new technology introduced is continuously being tested by the Agricultural Research Institute in order to evaluate the different systems under local conditions and select the appropriate irrigation method for each crop. The progress in the irrigation efficiency from less than 45% in 1960, reached 71% in 1980, 80% in

1990, 84% in 2000 and 90–95% in 2010. The on-farm irrigation systems comprise 90% micro-irrigation, 5% sprinkler irrigation and 5% surface irrigation (WDD, 2011b). Furthermore, the Agricultural Research Institute is conducting research for the design and application of hydroponics systems and the production of irrigation water through air condensation, in order for further savings in irrigation water to be achieved.

– *Irrigation scheduling*. Decisions on when and how much to irrigate are critical both to water use efficiency and to crop health. Irrigation scheduling aims at determining the exact amount of water to irrigate and the exact timing for application. Irrigation scheduling offers an opportunity for improving water efficiency at farm level and depend on private initiatives so its application cannot be considered wide. To further promote its application, the Rural Development Programme 2007-2013 of Cyprus is providing incentives to farmers for the implementation the application of integrated production management in the cultivation of potatoes and citrus, which inter alia foresees the sustainable use of water by following certain irrigation programmes and irrigation schedules.

ii) <u>Reduce run-off</u>

A number of practices applied in agriculture contribute to the reduction of run-off, such as terracing, contour plowing, installation of hedgerows, application of advanced irrigation systems and fire protection measures. The Good Agricultural and Environmental Conditions, a group of measures foreseen under the Cross Compliance[25] of the Rural Development Programme of Cyprus, include a number of standards for reducing run-off, which include:

– *Minimum soil cover*: There should be a natural / plant vegetation for the cover of land with a slope greater than 10% during the period of rainfalls.
– *Minimum land management reflecting site-specific conditions*: In a land with a slope greater than 10%, contour plowing must be exercised. Soil cultivating during periods of heavy rain should be avoided, especially in clay and heavy soils.
– *Terracing*: Terraces / stone walls and natural slopes at the boundaries of the crop holdings should be maintained. The construction of terraces is also financially promoted through the Rural Development Programme.

However, the implementation of these practices are mandatory only for those farmers receiving direct payments from the RDP, while their independent implementation depends on private initiatives on farm level based on farmer’s awareness on the issue and on the available methods for dealing with it.

iii) Use less water intensive crops

[25] Minimum requirements that farmers receiving direct payments must comply with

The existing crop patterns in Cyprus have been developed many years ago, when water availability was substantially higher. The decrease of water availability during the last years highlights the need to turn to less water intensive crops. However, this is a rather time-consuming process as most farmers have been adjusted to certain crops in terms of experience, know-how and equipment.

Among the proposed measures in the Programme of Measures of the Cyprus River Basin Management Plan (WDD, 2011a, - Annex III), the carrying of a study on the readjustment of crops towards a less water intensive crop mix in collaboration with the Department of Agriculture, the Agricultural Research Institute, the Ministry of Commerce, agricultural organizations, etc was proposed.

(c) Increase crop productivity

The increase in crop productivity is achieved through (i) the application of crop rotation, (ii) fertilization and (iii) using crops more resistant to hot and dry climates.

i) Crop rotation

The application of crop rotation and fallow on cultivated land is also associated with greater soil organic matter, soil structure and aggregation compared to simple rotations or mono-cropping. However, this practice entails that for at least one year there will be no revenues as there will be no crops cultivated. To compensate for these losses, the Rural Development Programme 2007-2013 of Cyprus is providing incentives to farmers for the implementation of crop rotation in crops of potatoes and arables.

ii) Fertilization

Management practices that enhance soil fertility apart from the use of chemical fertilizers and crop rotation, include the application of organic residues which are rich in nutrients (e.g. humus) to soil. The Good Agricultural and Environmental Conditions foreseen under the Cross Compliance[26] of the Rural Development Programme of Cyprus, include a set of standards for managing crop residues and suggest that depending on weather conditions, producers may use plant residues as soil cover or integrate them in the soil for annual crops.

It must be mentioned that the common practice in Cyprus for increasing crop productivity is the use of chemical fertilizers. Fertilization with chemical products although significantly contributes to the enhancement of soil fertility, is not considered a sustainable practice as it results in the pollution of water with the leaching of nitrates and is restricted by law on stressed areas.

iii) Use crops more resistant to hot and dry climates

[26] Minimum requirements that farmers receiving direct payments must comply with

Crop productivity under adverse climatic conditions may be ensured by the genetic improvement of plants in order to increase their resistance to those conditions and reinforce their adaptive capacity to climate change. The Agricultural Research Institute of Cyprus is conducting a research on the genetic improvement of plants for adaptation to climate change. Specific objectives of this research are the increase in crop yields, the increase of the resistance to abiotic and biotic stresses and the genetic improvement of a local variety of beans (*louvi*) and barley for increased adaptability to the warm and dry environment of Cyprus. These varieties were selected due to their substantial economic importance for Cyprus.

Considering the number of measures applied in Cyprus that contribute to the enhancement of the adaptive capacity of crop productivity to climate changes as well as the level of their adoption, their integration into farm practices and their effectiveness, it is estimated that the adaptive capacity towards this impact is **limited to moderate**.

7.4.2 Soil fertility

7.4.2.1 Assessment of sensitivity and exposure

Agricultural land in Cyprus and especially arable land and land used for permanent crops, which constitutes approximately 70% of the total agricultural land, is sensitive to erosion mainly due to the intensive cultivation and overexploitation of land resources, which overburden the soil and reduce its productivity. The exposure of agricultural land to erosion is considered as very high, as during the period 1980 – 1999, on average 55% or 1,220 km^2 of agricultural land was eroded from which 99% (1,200 km^2) was arable land and land used for permanent crops and 1% was meadows and pastures (see (MANRE, 2007).

Overexploitation has in many cases led to depletion of aquifers and, often to salinization of groundwater due to sea intrusion in coastal aquifers. The agricultural land located at the coasts is sensitive to soil salinization under a potential long-term use of these waters for irrigation due to the degradation of the colloidal phase of the soils, the high build-up of salinity and the high concentration of toxic elements which will inevitably affect commercial growing plants. As shown in Figure 7-24, the majority of coastal crops are located in the south - eastern part of Cyprus. However, it must be noted that, the main source of irrigation in coastal areas, during periods of sufficient water availability, is Government Water Works which is characterized by good quality water, while during drought periods the water supply for irrigation by Government Water Works is restricted in order to meet water demand for the domestic sector first, and thus, more groundwater is drilled from private boreholes in order to meet the demand for irrigation, accounting for approximately 50% of the total water used for irrigation. Thus, it is considered that since the coastal crops are not constantly irrigated with low quality water, their exposure to the risk of soil salinization is moderate.

Furthermore, the combined evaluation of Figure 7-25 and Figure 7-26, showed that the majority of crops cultivated in Cyprus are located in areas which are considered as critical to desertification, and therefore their exposure to desertification is characterized as high.

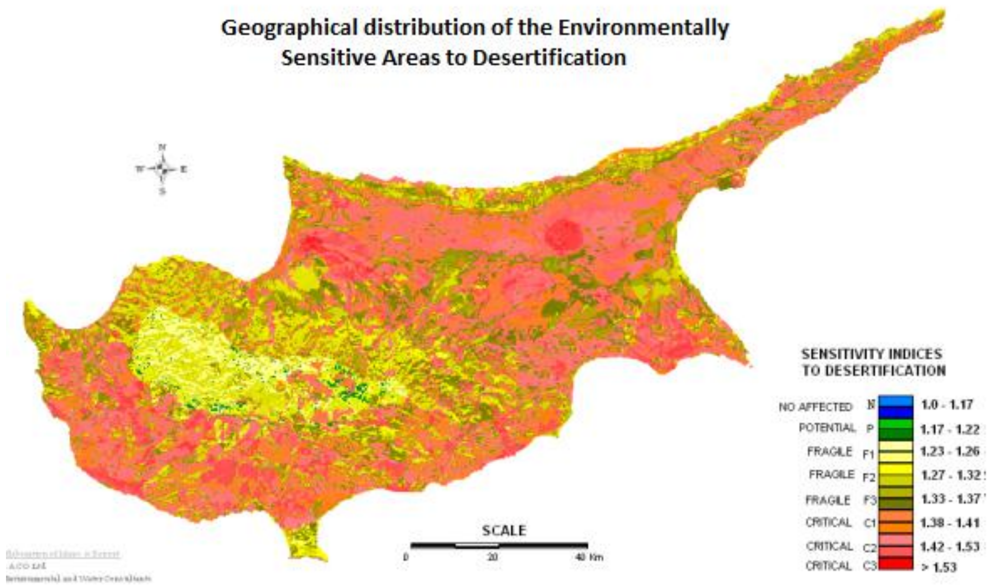


Figure 7-25: Geographical distribution of the Environmentally Sensitive Areas to Desertification

Source: I.A.CO Ltd, 2007

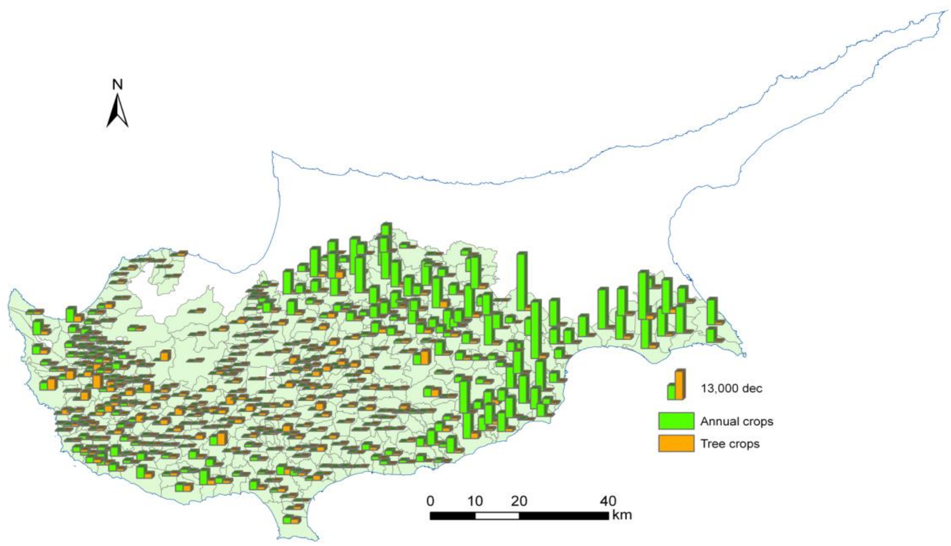


Figure 7-26: Geographical distribution of crops in Cyprus (Bruggeman et al., 2011d)

Considering the abovementioned climate change impact indicators for soil fertility, it is concluded that the agricultural sector of Cyprus has **moderate** sensitivity and **high** exposure to climate changes.

7.4.2.2 Assessment of adaptive capacity

In order to address degradation of arable land caused by intensive cultivation and overexploitation of land resources in Cyprus, the substitution of the use of chemical products in agriculture is encouraged with the provision of economic incentives for the application of the following eligible activities under the Rural Development Programme of Cyprus (2007-2013): (i) mechanical instead of chemical destruction of weeds, (ii) integrated production management and (iii) organic production.

i) The mechanical destruction of weeds is promoted through certain measures foreseen under the RDP, which refer to the cultivation of wine / table grapes and citrus.

ii) The integrated production management which involves inter alia the application of integrated pest management with the use of pheromones, traps, natural predators instead of chemical pesticides is promoted through certain measures of the RDP which refer to the cultivation of potatoes and citrus.

iii) The organic production which involves inter alia the production of agricultural products, without the use of chemical fertilizers and pesticides, in accordance with the provisions of Regulations 2092/91 is promoted through the RDP.

Additionally, guidance and technical support is provided to farmers regarding salinity and infiltration problems, and irrigation management methods for overcoming them, as well as guidelines and indicative concentration limit values for crops.

Even though there is a plethora of measures and different approaches which could be employed by farmers for mitigating risk of reduced soil fertility, their implementation are mandatory only for those farmers who have undertaken the commitment to implement those measures, while their independent implementation is rather costly and depends on private initiatives on farm level based on farmer's awareness on the issue and on the available methods for dealing with it. Thus, the current adaptive capacity of Cyprus' agriculture towards this impact is considered as **limited to moderate**.

7.4.3 Pests and diseases

7.4.3.1 Assessment of sensitivity and exposure

There are no available data for the determination of the sensitivity and exposure of the agriculture in Cyprus to pests and diseases due to climate changes. However, there are some indicative indicators which could be investigated in order to evaluate sensitivity towards this impact, are the identification of plant species that are in competition with the agricultural crops, pest patterns, diseases favoured by the Cypriot climatic conditions as well as the crops which are sensitive to diseases. Moreover, the magnitude of the exposure could be estimated by gathering information regarding the number of pest outbreaks, the areas covered by weeds and the recorded incidents of plant diseases.

7.4.3.2 Assessment of adaptive capacity

The measures that have been undertaken in Cyprus to support farmers in order to reduce the proliferation of new pests and diseases are categorized into four groups: (a) promotion of indigenous and locally adapted plants and animals, (b) development of an Integrated Pest Management Strategy, (c) application of crop rotation and (d) resistance enhancement of existing plants and animals against pests and diseases. The four groups are presented in detail below.

(a) Promote indigenous and locally adapted plants

The concept of this measure in relation to climate change adaptation lies on the fact that indigenous and locally-adapted plants and animals of Cyprus are more resistant to the climatic conditions of Cyprus and therefore they are less likely to be susceptible to infestations. Relative measures undertaken in Cyprus are the provision of financial support to farmers under the Rural Development Programme for the cultivation of traditional wine grapes and, on research level, the identification and promotion of endemic flora species for cultivation.

(b) Develop an Integrated Pest Management Strategy

The role of an Integrated Pest Management Strategy towards the reduction of pests is mainly preventive, as it includes measures for the prevention of infestation by promoting plant varieties which best adapt to local growing conditions, as well as for the monitoring of pests patterns to prevent damages. Although no such strategy has yet been enforced in Cyprus, the Agricultural Research Institute of Cyprus has undertaken a research project for the integrated and biological treatment of insects and mites in annual and perennial crops.

(c) Apply crop rotation

Pest and pathogens may also be reduced by applying crop rotation on cultivated land, as the changing of crops in a sequence disrupts the pest (weeds and insects) and pathogen life cycles. Thus, the build-up of pest and pathogen populations is obstructed. As mentioned also above, the Rural Development Programme 2007-2013 of Cyprus is providing economic incentives to farmers for the implementation of crop rotation on the cultivation of potatoes and arables.

(d) Reinforce resistance of existing plants against pests and diseases

The resistance of plants against pests and diseases can be reinforced by the application of biotechnology for the plant health improvement and their strengthening against future health risks. On this direction, the Agricultural Research Institute of Cyprus is investigating the local production of healthy propagating material of various cultivars which will enable inter alia the elimination of infestations. For that reason, an *in vitro* Seed Bank has been created for the preservation of healthy propagating material.

It must be mentioned that the common practice in Cyprus for dealing with pests and diseases is the use of chemical products (e.g. pesticides) for their destruction. Although it constitutes an effective method for the temporary solution of the problem, the intensive use of pesticides increases the resistance of pests to pesticides and reduces the plant self-resistant capacity, thus reducing their long-term effectiveness. Furthermore, the application of chemical products is not considered as an acceptable and sustainable method due to the degradation it creates to the quality of soils and water.

However, in absence of data on the magnitude of the impact of climate changes on pests and diseases on crops, the adaptive capacity towards this impact cannot be evaluated.

7.4.4 Damages to crops from extreme weather events

7.4.4.1 Assessment of sensitivity and exposure

The sensitivity of crops to extreme weather events is evaluated based on the extent of the damage caused to them by crop and by extreme event while the exposure is assessed based on the frequency of the extreme climatic events causing damages to crops in Cyprus.

The lion's share in compensations provided by the Agricultural Insurance Organization (AIO) of Cyprus for losses to crops caused by extreme climatic events for the period 1978-2009 is possessed by cereal and dry fodder crops, with a percentage of 41.5% (€65 million) of total compensations granted during that period. However, it must be mentioned that the amount of compensations paid for cereals and fodder crops is high mainly due to the large area of arable land covered for the cultivation of these crops (63% of the total crop area, see also

Figure 7-2) and not due to the severity of the effect of droughts on these crops. The second place is occupied by potato crops with a percentage of 28% (€44 million) of total compensations followed by deciduous crops with 13.5% (€21 million), vines with 9.2% (€14.5 million) and citrus with 7% (€11 million) (Ioannou, 2010). In the following figure, the contribution of each crop to the total compensations provided by the AIO in Cyprus during the period 1987-2007, is illustrated.

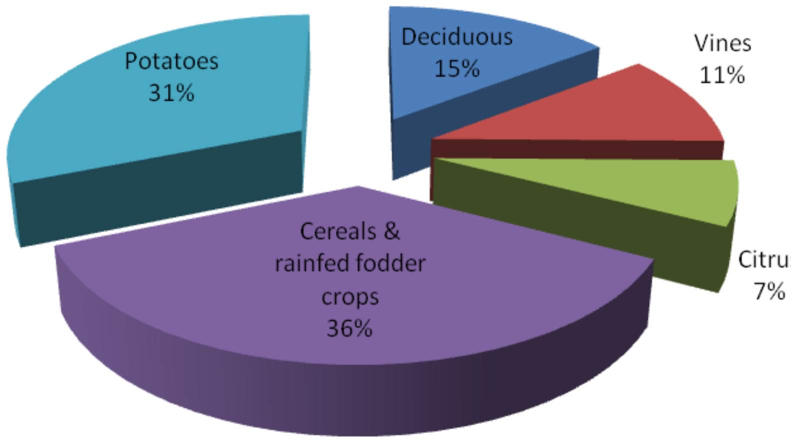


Figure 7-27: Contribution of the compensations paid to main crops affected to the total compensations provided in Cyprus during the period 1987-2007 (CYPADAPT)

Source: AIO, 2008a

The extreme weather event causing the majority of damages to crops during the period 1978-2009 and which was mostly compensated for, is drought in cereals and dry fodder crops (€62.5 million). However, it must be mentioned once more that the damaging effects of drought are not so intense, considering that the compensations paid for cereals and fodder crops are high mainly due to the fact that they cover a large area of arable land (63% of the total crop area, see also Figure 7-2). Hail and frost are the second most damaging extreme weather event in Cyprus with quite high compensations provided for the damages caused to almost all crops (€42 million each), while heat waves which are in the third place have been considerably less compensated for (€3.5 million), with damages caused mainly to vines. With regard to the rest of extreme weather events, the total compensation provided for the damages that caused to crops was significantly lower (€6 million in total) (Ioannou, 2010).

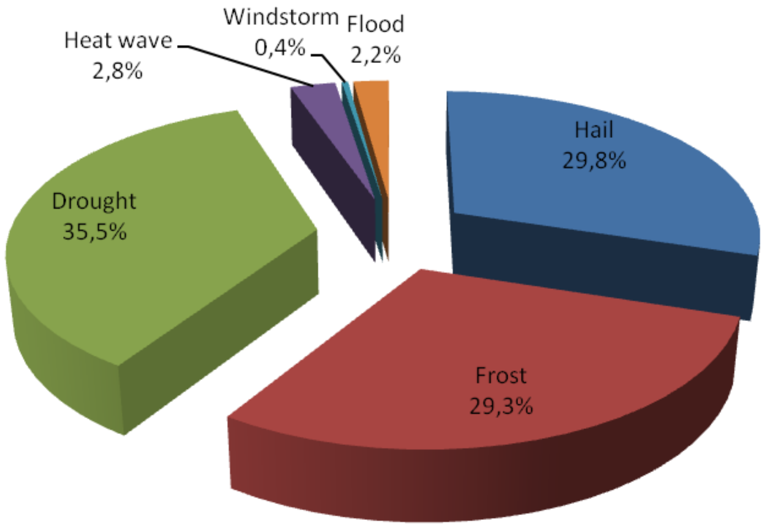


Figure 7-28: Contribution of compensations paid for the main extreme weather events to the total compensations provided in Cyprus during the period 1987-2007 (CYPADAPT)

Source: AIO, 2008b

The common damaging extreme climatic event is hail, since when it occurs almost all crops are affected with extensive damages (Ioannou, 2010). Hail was found to be the most damaging factor to deciduous plantations. Mountainous plantations whose contribution to the total compensation is the greatest, like deciduous trees and vines, are primarily affected by thermal instability hail events, while frontal instability hail events are responsible for the high compensation for plantations of potatoes (Nicolaides et al., 2009).

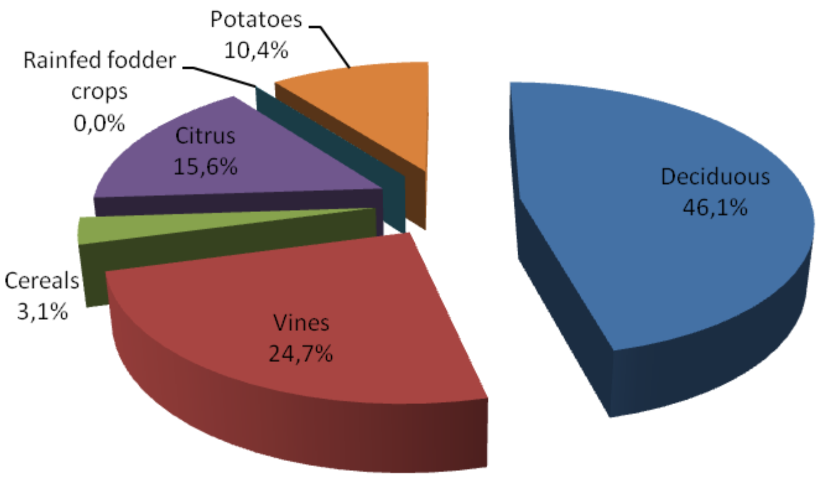


Figure 7-29: Compensations provided to farmers for damages caused to crops by hail events, 1978-2007 (CYPADAPT)

Source: AIO, 2008b

Therefore, it is estimated that the sensitivity of crops cultivated in Cyprus to extreme climatic events is **high**.

With regard to exposure, from the statistical analysis of the data provided by the AIO (2008b) it was observed that compensations for damages by hail events were paid every year from the establishment of the AIO in 1978 until 2007 with a frequency of occurrence 100%, followed by compensations for frosts with a frequency of occurrence 83%, droughts with 70%, heatwaves and windstorms with 53% each and floods with 47%. Considering the above, the exposure of the agricultural sector of Cyprus to extreme climatic events is characterized as **moderate to high**.

7.4.4.2 Assessment of adaptive capacity

For the protection of crops against droughts, a plethora of measures have been undertaken or promoted in order to increase water availability for irrigation and reduce run-off, as also described in Section 7.4.1.2. However, in spite of the measures, water demand for irrigation during drought events is not fully met in most cases, and thus the adaptive capacity of crops to droughts is considered limited to moderate.

Plantations of hedgerows of shrubs or trees help protect agricultural crops from external factors such as floods, winds and frosts, thereby reducing damage to crops while improving the quality and quantity of agricultural production. To promote the implementation of such measures, financial support is provided through the Rural Development Programme 2007-2013 of Cyprus for the installation of windbreaks, which are actually hedgerows of forest trees, around agricultural crops. In addition, irrigation with sprinklers protects from frosts. The installation of advanced irrigation systems such as sprinklers, is also financially supported by the Government.

Furthermore, woodlands help buffer peak rainfall events, prevent flooding and waterlogging by slowing the movement of water from soil to watercourses. To promote the implementation of such measures, financial support is provided through the Rural Development Programme 2007-2013 of Cyprus for the establishment of woodlands.

The destructive effects of hails to crops may be prevented by covering crops with nets, however it requires the timely forecast of the event and the rapid response of farmers for the placement of the net. Finally, the options for the protection of crops from heatwaves are limited.

In general, the abovementioned measures for the protection of crops from extreme events, are applied on farm level and hence their implementation depends on the private initiative of farmers. Considering the above the adaptive capacity to this impact is characterized as **limited to moderate**.

7.4.5 Livestock productivity

7.4.5.1 Assessment of sensitivity and exposure

There are no available data for the determination of the sensitivity and exposure of livestock productivity in Cyprus to climate changes. However, some indicative indicators which could be investigated in order to evaluate sensitivity towards this impact, are the animal species which are more sensitive to increased temperatures and heat waves and the percentage of their population over the total animal population in husbandry, as well as the sensitivity of conception and production rates during extended warm periods. The exposure can be estimated based on the assessment of data on the frequency of extended warm periods in Cyprus, on the reduction of the available animal feed, on the incidents of diseases outbreaks and heat stress on livestock and on the percentage of livestock with no housing and ventilation facilities.

7.4.5.2 Assessment of adaptive capacity

Catering for animal welfare under adverse weather conditions can be enhanced by increasing the amount of shade and shelter or by keeping livestock indoors.

Shelterbelts provide protection from heat and wind for livestock. Planting tall, fast-growing, trees on the southern edge of pastures is one method of increasing shade. The implementation of this measure is promoted through the Rural Development Programme with the provision of economic incentives for the plantation of hedgerows of forest trees.

In addition, the use of thermostats, cooling and ventilation systems within animal housing areas may be used to maintain temperature in acceptable levels and thus reduce heat stress and disease outbreaks. The implementation of this measure is promoted through the Rural Development Programme 2007-2013 of Cyprus which provides financial support to farmers for the installation of ventilation systems in animal housing areas.

Another measure adopted which also contributes to the increase of the sector’s adaptive capacity is the establishment of a gene bank for animal species in order to protect genetic diversity.

Furthermore, the Ministry of Agriculture, Natural Resources and Environment of Cyprus in order to support the efforts made by Cypriot farmers, focuses on the increasing of animal productivity by promoting improved breeding and management methods, improving veterinary services for animal disease control and treatment, local production of animal feed, and upgrading of farm units through mechanization and enhancing the management skills of farmers (http://www.cyprus.gov.cy).

However, in absence of data on the magnitude of the impact of climate changes on livestock productivity, the adaptive capacity towards this impact cannot be evaluated.

7.4.6 Costs for livestock catering

7.4.6.1 Assessment of sensitivity and exposure

There are no available data for the determination of the sensitivity and exposure of costs for livestock catering in Cyprus to climate changes. However, some indicative indicators which could be investigated in order to evaluate sensitivity and exposure towards this impact, are the increase in costs for livestock catering during extended warm periods in Cyprus, the deficit in local animal feed production and the excess costs for importing animal feed, for providing housing, ventilation, etc.

7.4.6.2 Assessment of adaptive capacity

The measures for enhancing adaptive capacity to increased costs for livestock catering are related mainly to the financial support provided by the Rural Development Programme of Cyprus for improving outdoor and indoor conditions for livestock, as also mentioned in Section 7.4.5.2.

However, in absence of data on the magnitude of the impact of climate changes on the costs for livestock catering, the adaptive capacity towards this impact cannot be evaluated.

7.4.7 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of the agricultural sector of Cyprus to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of the agricultural sector against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used.

The results of the vulnerability assessment for the agricultural sector in Cyprus are summarized in Table 7-8.

Table 7-8: Overall vulnerability assessment of the agricultural sector in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Crop yield	Very high (7)	High (5)	Limited to Moderate (2)	Moderate to High (3.9)
Soil fertility	Moderate (3)	High (5)	Limited to Moderate (2)	Limited to Moderate (1.9)
Pests and diseases	Not evaluated	Not evaluated	Not evaluated	-
Damages to crops from extreme weather events	High (5)	Moderate to High (4)	Limited to Moderate (2)	Moderate (2.5)
Livestock productivity	Not evaluated	Not evaluated	Not evaluated	-
Costs for livestock catering	Not evaluated	Not evaluated	Not evaluated	-

As it may be observed from the table above, the first vulnerability priority of the sector is the impact of climate changes on crop yield, as the latter have been significantly reduced during the last years as a result of adverse climate conditions which impede crop productivity. The second priority of the sector regarding its vulnerability to climate changes is related to the damages caused to crops due to extreme weather events, taking into consideration their devastating effect and the magnitude of their effect on crops as well as the fact that climate changes are expected to increase in frequency and intensity. The last priority is the impact of climate changes on soil fertility, whose condition is already deteriorated. For the rest of the identified impacts, no evaluation took place due to lack of sufficient data.

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8 FORESTS

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Abbreviations and Acronyms

CIAM	Centre for Integrated Assessment Modelling
CYSTAT	Statistical Service of Cyprus
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resources Assessment Programme
FWI	Fire Weather Index
GDP	Gross Domestic Product
ICP-Forests	International Co-operative Program on the Assessment and Monitoring of Air Pollution Effects on Forests
IPCC	Intergovernmental Panel on Climate Change
LTRAP	Long-range Transmission of Air Pollutants in Europe
MANRE	Ministry of Agriculture, Natural Resources and Environment
NFP	National Forest Programme
ODS	Ozone Depleting Substances
OWL	Other Wooded Land
UNECE	United Nations Economic Commission for Europe

8.1 Climate change and forests

Climate influences the structure and function of forest ecosystems and plays an essential role in forest health. Changes in global climate are already stressing forests through higher mean annual temperatures, more frequent and extreme weather events and altered precipitation patterns (FAO, 2008; Weiskel, 2009) which may worsen many of the existing threats to forests, such as pest outbreaks, fires and droughts. Climate changes affect directly and indirectly the growth and productivity of forests; directly due to changes in atmospheric carbon dioxide and climate and indirectly through compositional and functional changes taking place in forest ecosystems (Van Bodegom et al., 2009; EPA, 2012).

For Mediterranean regions, such as Cyprus, where water availability restricts the productivity and growth of forests, the effects of high temperatures can be detrimental, especially if the precipitation does not increase or shifts to the winter season as projected (Loustau *et al.,* 2005). Another issue concerning the Mediterranean region is the high forest fire risk which constitutes the largest threat mainly during the summer period because of the climatic conditions (long, hot and dry summers and strong winds) (Lindner *et al.,* 2010).

On the other hand, forests play a major role in mitigating climate change provided that they trap and store carbon dioxide. When forests are destroyed, overharvested or burned could become sources of greenhouse gases such as carbon dioxide (FAO, 2008; Weiskel, 2009).

Forests and their management are particularly sensitive to climate change because the long lifespan of trees does not allow a rapid adaptation to environmental changes (Lindner *et al.,* 2010).

It is essential to protect the forests of Cyprus from the threats posed by climate change as they are an important national resource. Forests provide timber and non-wood products, they contribute significantly to the beauty of the landscape, the preservation of the national heritage, the protection of water supplies, rural life, village communities and the general well-being of Cypriot citizens. The future prosperity of the country is bound up with its forests and what happens to them (Christodoulou, 2003).

8.2 Baseline situation

8.2.1 The current state of forest resources

The forest areas in Cyprus are classified in two major groups: a) forests and b) other wooded land, OWL (incl. maquis and garique) which are either of state or private ownership. The two groups account for 42.3% (390,944 ha) of the total land area. The distribution of forest areas in these groups is shown on Table 8-1. The total cover of forest & OWL areas in Cyprus (42.3%) is close to the average of the EU (44%), whereas the forest cover only (excl. OWL) (18.7%) is about half of the average of the EU (36,4%). Almost all forest areas are either natural (primary-undisturbed by man) or semi-natural. High forests comprise 44.2% of the total forest area, though maquis and lower vegetation such as scrub and phrygana account for 55.8%. Unlike most European countries, Cyprus forests are mainly public. State forests constitute 68.8% of the total forest area in Cyprus while the rest 31.2% is in private ownership. The ownership is reversed when referring to OWL, as 34.6% of the OWL is public and the rest 65.4% is privately owned. (Department of Forests, 2011a).

Table 8-1: Forest ownership and area

Forest Ownership		Area (ha)	Area Percent.	Area Total (ha)	Area total Percent.
Public	Forests	118,915	12.9%	194,420	21.0%
	OWL	75,505	8.2%		
Private	Forests	53,914	5.8%	196,524	21.2%
	OWL	142,610	15.4%		
Total Forest & OWL		**390,944**	**42.3%**	**390,944**	**42.3%**
Other Land *		**534,206**	**57.7%**	**534,206**	**57.7%**
Total		**925,150**			

OWL: Other wooded land (includes maquis and garique)

[*] The rest of the island's area (including 3,500 ha of water bodies)

Source: Department of Forests, 2011a

State forests are mainly confined to the Troodos mountain range in the central part of the island and the Pentadaktylos mountain range in the northern part. Out of total forests' area, approximately 76% is found in the government controlled areas and 24% in the areas occupied by Turkey (Michaelidou *et al.,* 2004). Forest vegetation is mainly found along the Troodos and Pentadaktylos ranges and along the coastal belt. Forest vegetation is lacking from the central plain of Mesaoria, which is characterized as semi-arid zone with some exceptions. In general, the extent of forest vegetation is affected by the ecological conditions, particularly by the prolonged dry season. Garigue vegetation (predominantly low shrubs), which generally include the low 0.5 to 0.8 meters open sclerophyllous sub-shrubs, is found on degraded and sloping soils. In areas with higher potential, garigue is succeeded by maquis (evergreen sclerophyllous shrubs), while pine forests are considered the climax vegetation. Maquis vegetation includes the evergreen and densely branched shrubs, 2 to 5 meters in height with thick, dark green, leathery and usually small leaves (Department of Forests, 2006).

The geographic distribution of forest, garigue and maquis vegetation areas in Cyprus is illustrated in the following figure.

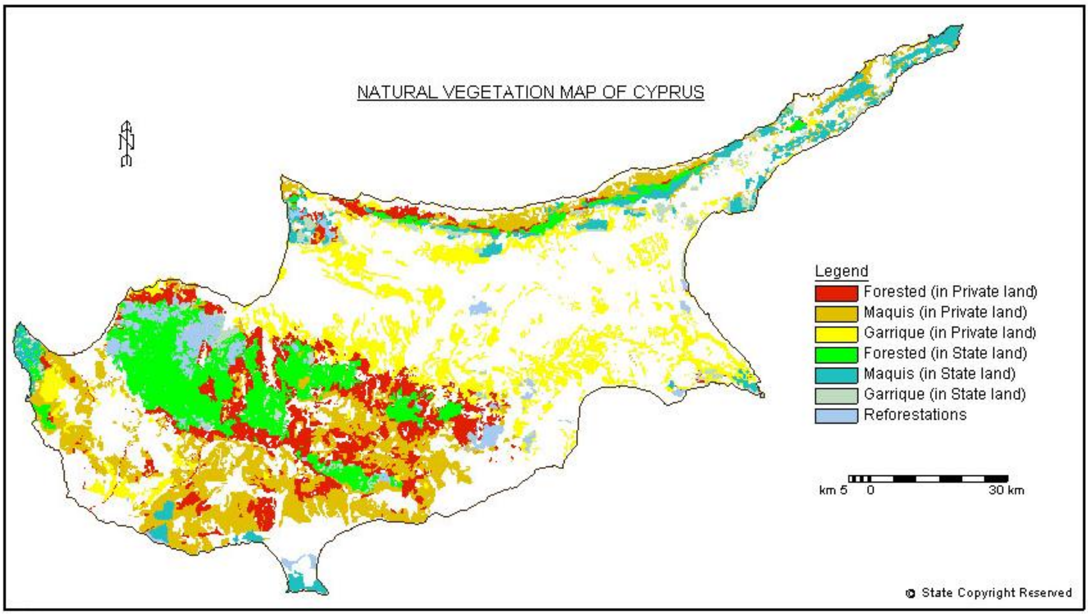


Figure 8-1: Natural vegetation of Cyprus

Source: Department of Forests, 2011a

In the context of the forest law, State Forests are categorized into two categories Main and Minor State Forests, which are subdivided as follows:

Main State Forests (Permanent Forest Reserves, National Forest Parks, Natural Reserves): Main State forests occupy the two mountain ranges, the Southern Troodos Massif and the Northern Pentadactylos Range. The Troodos mountain range is of particularly high ecological significance, not only because it contains rich plant and avian diversity, but also because it feeds most river basins and aquifers of the island, with maximum precipitation of 1000 mm/year. These forests consist of a variety of natural vegetation including forests of conifers and broad-leaved trees such as pines, cypress, cedars and oaks. Up to 1,400 m the dominant vegetation is Calabrian pine forest (Pinus brutia), which constitute the productive forest of the island. At higher elevation (1,400-1,950 m) the black pine forest (Pinus nigra ssp. pallasiana) dominates up to the highest peak (Department of Forests, 2011a).

Minor State Forests (Multiple Use Forests, Communal Forests, Municipal Forests, Nursery Gardens, Grazing Areas): Minor State Forests are lowland forests and many of them are coastal. They are mostly found in the districts of Ammochostos and Limassol, while the majority of them are now under Turkish occupation. They are covered by maqui vegetation, mainly composed of Juniperous phoenicea, Olea europaea, Ceratonia siliqua, Pistacia lentiscus, Pistacia terebinthus and scattered Pinus brutia (Department of Forests, Cyprus 2011a).

Main and Minor State forests of Cyprus are depicted in the following map (Figure 8-2).

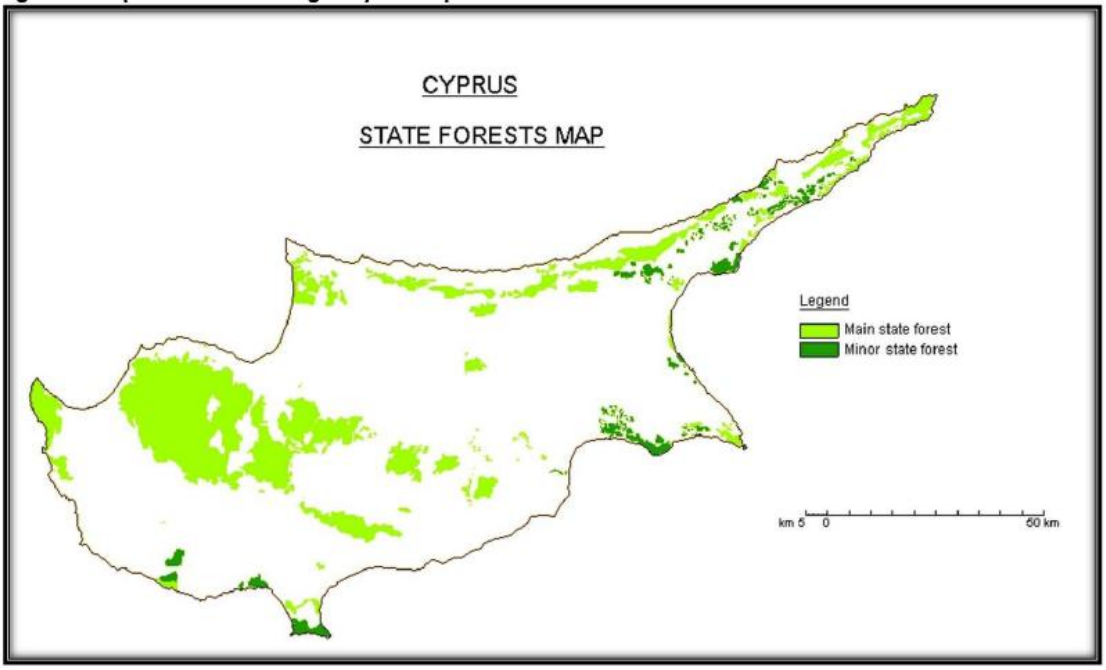


Figure 8-2: State Forests of Cyprus

In specific, Cyprus' forests are dominated by coniferous species forming pure or mixed stands. The main native tree species are Pinus brutia, Pinus nigra ssp. pallasiana, Cedrus brervifolia, Cupressus sempervirens, Juniperus phoetidissima, Juniperus excela, Platanus orientalis, Alnus orientalis, Quercus infectoria ssp. Veneris (Department of Forests, 2011a). The major forest types of Cyprus are shown in Table 8-2.

Table 8-2: Major forest types, categories and species

Major Forest type Total forest	Area (covered by forest type) (ha)Year:2010	Main species	
		Trees	Other species
All conifers	172,052	Pinus brutia	Quercus alnifolia (Cyprus Oak) Arbutus andrachne Pistacia lentiscus Pistacia terebinthus Rhus coriaria Quercus coccifera
		Pinus nigra ssp. pallasiana Pinus pinea	
		Cedrus brevifolia Juniperus foetidissima	
		Juniperus excelsa	
		Juniperus phoenicea	

Major Forest type Total forest	Area (covered by forest type) (ha)Year:2010	Main species	
		Trees	Other species
		(Shrub)	
		Cupressus sempervirens	
Broadleaves	1,130	Platanus orientalis	
		Alnus orientalis Salix alba	
		Ceratonia siliqua Olea europaea	
		Quercus infectoria ssp. veneris	
		Populus ssp.	

Source: FRA, 2010

Afforestation and reforestation have been major activities on Cyprus ever since the British assumed control of the island in 1878. Planted forests cover 2.3 % of total forest area (Department of Forests, 20011a). Initially, several species of Eucalyptus were introduced. However, today, much of the plantations are composed of the indigenous species, Pinus brutia. More recently, mixed species plantations of P. brutia, P. halapensis, Cupressus sempervirens and occasionally P. pinea have been established (FAO, 2008).

8.2.2 Forestry

The GDP share of the forestry sector in Cyprus is generally low, presenting a declining trend over the last decade. Based on data collected from the Department of Forests (2006), the annual contribution of forestry in the economy is negligible. In 2001, the contribution of forests in the total GDP was 0.026% while this of timber based industries (sawmilling, wood based panels and wooden pallets) as well as wooden furniture manufacturing was more significant. That contribution was accounted for 1.1% of the total GDP. Additionally, the national annual wood production estimated at 8000 m^3/year, an amount which is not sufficient to support the primary wood processing industries of the island. The national timber production accounts for only 8% of the total consumption compared to the imported timber and timber products necessitating the import of final products (Department of Forests, 2006).
The main commercial value species of Cyprus forests is Pinus brutia (native tree species) that constitutes about 90% of the growing stock. This is the only species that is actively managed for timber production constituting about 60% of the State Forests. The particular species is

utilized as solid wood products and fuels for energy production (Department of Forests, 2011).

Table 8-3: Total growing stock of Cyprus

Forest Type	Area Covered (ha)				Estimated growing stock (m^3)			
	1990	2000	2005	2007	1990	2000	2005	2007
All Forests	161,110	172,770	172,851	172,853	7 404 950	7 929 650	8 382 748	8 554 566
All conifers	160,110	171,770	171,721	171,723	7 204 950	7 729 650	8 156 748	8 328 566
Broadleaves´forests	1,000	1,000	1,130	1,130	200,000	200,000	226,000	226,000
Pinus brutia forest	n.a.	n.a.	137,744	137,744	n.a.	n.a.	7 414 750	7 600 430

The data of the table above indicate an increase by only 7.3% in 17 years period of the total area covered by forests, while the growing stock is estimated to increase by 15.5% throughout this period.

Due to the climatic conditions, the growth of Pinus brutia is very low and the yield can satisfy only a small portion of the local demand for wood. Therefore, forest resources in Cyprus are mainly used for environmental and ecological contribution and secondary for economic contribution.

8.2.3 Pressures

Cyprus forests. like all forests, are threatened by a variety of agents, both abiotic and biotic as well as human induced ones. Non climate related pressures are mainly associated with (i) unsustainable timber harvesting, (ii) overgazing which causes degradation not only on the vegetation but also on the soil and water regime of the island and (iii) land development especially for tourism development and construction of holiday dwellings. Intensive tourism development in State Forest land causes degradation, soil erosion and compaction, pressure on sensitive flora and fauna species, water quantity and quality and increase of pollution (Department of Forests, 2011a).

Timber harvesting, forest fires and overgrazing have transformed large forest areas into degraded shrub lands while land clearance and terracing of hillslopes for crop production killed almost all of the Island's oak forests (Ciesla, 2004).

According to the CORINE 2006 land cover of the island of Cyprus, forests covered 16.7% of the total island area presenting an overall reduction of 7.1% compared to the respective data from CORINE 2000, while natural grasslands, shrubs and sclerophylous vegetation covered 24.4% of the total land in 2006 presenting an increase of 12.3% compared to 2000 (EEA, 2011). The detailed data are presented in Table 8-4 below.

Table 8-4: CORINE 2000 and 2006 land cover of the island of Cyprus

	Hectares in 2000	% of total land cover in 2000	Hectares in 2006	% of total land cover in 2006	Change in land cover 2000-2006
Broad-leaved forest	763	0.08%	723	0.08%	-5.5%
Coniferous forest	155,165	16.77%	153,568	16.60%	-1.0%
Mixed forest	357	0.04%	355	0.04%	-0.6%
Natural grasslands	32,017	3.46%	28,175	3.05%	-13.6%
Schlerophylloys vegetation	161,138	17.42%	157,817	17.06%	-2.1%
Transitional woodland/shrub	28,492	3.08%	39,577	4.28%	28.0%

Source: EEA, 2011

In Cyprus there is a number of threatened species including plants, animals and other organisms. For Cyprus threatened forest species, detailed inventories are currently under way while the Cyprus Red Data Book of flora species has been developed. According to the IUCN criteria 163 plant species are threatened, due to small population size and distribution area (Department of Forests, 2009a).

8.2.4 Forest management

The need to manage the forest of Cyprus for multiple purposes has been clearly set out, right from the first official forest policy declaration in 1950. However, the emphasis previously given to timber production and meeting domestic requirements for wood products is no longer appropriate and a new balance is emerging (Christodoulou, 2003).

Cyprus has formulated a forest policy and a National Forest Programme, while starting a process of updating its forest legislation, laying the stress on environmental services and recreation rather than wood production. The national strategy for forests of Cyprus has two main thrusts: multiple use (protection, recreation and trade) and sustainability (ecological, economic and social). A participatory approach to forest management and its planning is introduced in the proposed new legislation, strategy and policy (FAO, 2010). The management of the State Forests is controlled by the forest law, which has been amended several times since its first enactment in 1879.

The National Forest Programme (NFP) of Cyprus covered the ten-year period 2001-2009. The NFP consists of a complex set of activities and related projects, which are designed to achieve the aims of the strategy. These sub-programmes deal with the following groups of activities (Christodoulou, 2003):

- Afforestation and silviculture
- Production of timber and non-wood products
- Protection against fires and other hazards
- Conservation of ecosystems, flora, fauna and heritage
- Water
- Local plans and village development
- Institutional reform, modernization and capacity building

During 2010, the first preliminary drafts of a new Forest Policy were developed while within the first quarter of 2011, these drafts were forwarded to the Council of Ministers for approval and to the House of Representatives for voting. The Department of Forests within the first half of 2011 and after finalizing the relevant texts proceeded with public consultation (Department of Forests, 2011a).

The Department of Forests of the Cyprus Republic is also participating in many other plans, including the Standing Forestry Committee of the European Commission which is currently working on the Climate Change mitigation. In addition, it is participating in the “Echoes Cost Action” which has as main objectives to mobilize and integrate the existing scientific knowledge for European forest policymakers and managers. The Action begun at 2008 and has a duration of 4 years. There are three working groups: Impacts, Adaptation and Mitigation (Weiskel, 2009).

8.3 Impact assessment

The direct impacts of climate change on Cyprus' forests arise mainly from temperature and precipitation changes as well as fires. Indirect impacts come from the interactions between changes in climatic variables and several abiotic and biotic factors (Lindner *et al.,* 2008).

Main abiotic disturbances in Europe have been caused by fires, wind storms, flooding and drought, all of which may be affected by climate change. In the period 1950-2000, an annual average of 35 million m^3 wood was damaged by disturbances; storms were responsible for 53% of the total damage and fire for 16%. Under climate change, the extreme weather patterns, (drought, flooding, wind storms), are projected to intensify. These extreme conditions have several direct and indirect impacts on the forests. As an example, in Europe the years 2003 and 2007 demonstrated that forest fires may be substantially more devastating when large scale droughts prevail. Fire in the Mediterranean regions, and wind damage especially in northern and Western Europe, may more frequently result in an imbalance in the long-term planning of harvests.

Biotic factors include disturbance agents such as insects and pathogens which affect directly and indirectly plant nutritional quality and plant resistance through changes in or through community interactions (e.g. natural enemies). The impact factors (atmospheric air pollution due to CO_2 increase, changes in temperature, changes in precipitation and in abiotic disturbances) seriously influence biotic disturbance agents.

Droughts in Cyprus cause dieback of tree species and secondary insect attacks but they also affect forestry regeneration and forest health, through the expansion of forest fires because of the increase of temperature and the decrease of precipitation, soil erosion, increase of dust in the atmosphere, decreased water availability and biodiversity loss (Department of Forests, 2009a).

Table 3-1 summarizes the observed and potential impacts of climate change on Cyprus' forests.

Table 8-5: Relationship between observed climate changes and impacts on the forest sector

Climate Change Factors	Forest impacts	
	Direct Impacts	Indirect Impacts
Drought	– Insect attacks – Dieback of trees – Pressure on fauna species – Biodiversity loss – Desertification	– Reduction of forestry regeneration and growth – Degradation of forest, impacts on forests' health and vitality – Increase in number and severity of forest fires – Soil erosion – Increase of dust in the

<table>
<tr><th rowspan="2">Climate Change Factors</th><th colspan="2">Forest impacts</th></tr>
<tr><th>Direct Impacts</th><th>Indirect Impacts</th></tr>
<tr><td></td><td></td><td>atmosphere
– Negative effect on reforestations and natural stands</td></tr>
<tr><td>Higher mean annual temperatures – Hot spells</td><td>– Insect attacks
– Dieback of trees
– Pressure on fauna species
– Biodiversity loss
– Desertification</td><td>– Increase in number and severity of forest fires
– Photosynthesis decrease
– Decrease of biomass growth and yield
– Decrease of forests’ productivity
– Decrease of wood production
– Effect on carbon sequestration rates and net carbon balance</td></tr>
<tr><td>Decreased precipitation</td><td colspan="2">– Change in competition among -plant species
– Nutrient availability in soils
– Deficiency in water for fauna</td></tr>
<tr><td>Increase of extreme events (floods, wind throws and storm damages)</td><td colspan="2">– Injuries
– Inhibition of seed germination
– Changes in plant anatomy
– Promotion of early senescence and mortality
– Nutrient availability in soils</td></tr>
<tr><td>Atmospheric CO_2 increase</td><td colspan="2" rowspan="2">– Increase in photosynthesis rates (varying with plant nitrogen status and species)
– Effects on forest growth, tree physiology
– Insect attacks</td></tr>
<tr><td>Increase in atmospheric nitrogen, ozone</td></tr>
</table>

The main direct and indirect impacts presented in the table above were grouped in the following impact categories:

- Dieback of tree species, insect attacks and diseases
- Fires
- Floods, wind throws and storm damages
- Forest growth

These impact categories are further analyzed in the following section.

8.3.1 Dieback of tree species, insect attacks and diseases

Climate change will affect temporal and spatial dynamics of pest species, influencing the frequency and consequences of outbreaks as well as their spatial patterns, size and geographical range. Insect outbreaks often defoliate, weaken, and kill trees. Climate change could contribute to an increase in the severity of future insect outbreaks. Rising temperatures may enable some insect species to develop faster and expand their ranges (EPA, 2012).

In Cyprus, the period of 2005-2008 was featured by extreme droughts resulting to the intense stress of forest ecosystems, particularly those found in lowland and hilly areas, due to the extremely low levels of soil moisture. The results of drought were necrosis of trees occurred and the development of secondary insects attack. The decrease in rainfall in the island and the increase in temperature resulted to the dieback of the tree species Cedrus brevifolia (Cyprus cedar). The warm and dry climate conditions make pine stands in the forests of Cyprus vulnerable to pests such as the pine processionary caterpillar and bark beetle.

In Cyprus, the lack of soil moisture, apart from its effects on the drying of trees, has secondary impacts on them since it enhances the activity of insects such as the Orthotomicus erosus and Bursaphelenchus leoni which attack stressed trees due to lack of moisture and dry them up altogether. The necrosis of a significant number of pines and cypress in Stavrovouni forest occurred due to the impact of insects during the dry period 2005 – 2008 (Department of Forests, 2011b; Cyprus Institute, 2011).

Insects are the main harmful forest organisms in the Cyprus forests. The typical Mediterranean climate with mild winters and hot, dry summers favours the breeding of harmful forest organisms in large populations. Ideal climatic conditions for breeding insects and in particular a few bark beetles result in the breeding of more than one generations per year (Department of Forests). Insect outbreaks are caused due to the rapid increase of populations such as fungi and bacteria inhabiting water stressed tree species in Cyprus (e.g. B. mediterranea on Quercus spp. and D. pinea on Pinus spp.) in a very short period, resulting in sudden forest dieback. Such shifts from latency to pathogenic stage in case of fitting environmental conditions, such as drought, pose a considerable threat to forests under changing climate (Lindner et al., 2010; Desprez-Loustau et al., 2006; Maresi et al., 2007). On the other hand, destructive diseases are not common in the forests of Cyprus because the environmental conditions are not favourable for breeding their agents with the exception of few cases (Department of Forests).

8.3.2 Fires

Fire danger is expected to increase throughout Europe, especially in the already fire-prone Mediterranean but also in the Boreal and central European regions. The impacts of fire on forests stands are considerable, especially at the fire prone Mediterranean and Continental regions. Possible effects on a single-stand scale are known. With regard to carbon cycling, the negative impact of fire on soils became of interest in the last years. Severe fires can cause significant removal of organic matter, deterioration of both structure and porosity, considerable loss of nutrients through volatilization, ash entrapment in smoke columns, leaching and erosion, and marked alteration of both quantity and specific composition of microbial and soil-dwelling invertebrate communities (Lindner *et al.,* 2008).

Forest fires are considered as a major and permanent threat for the forests of Cyprus. Every year, forest fires cause enormous and irreparable damage to forest ecosystems and in some cases threaten residential regions. There are many factors that contribute to an increased fire risk in Cyprus, such as high temperatures and prolonged drought periods, the strong winds, the configuration of the ground and the extremely flammable vegetation. The accumulation of biomass due to the abandonment of rural areas and the increasing tourism and exodus of city residents to forested areas, are also important factors which contribute to an increased fire risk, especially during summer months (Department of Forests, 2012).

According to the Cyprus Department of Forests (2012), the highest percentage of fires in Cyprus occurs due to human negligence and not natural causes. Cyprus possesses the 19th rank among 23 countries on records for forest fires as well as the burnt areas. However, regardless of what the cause of fire is, the impacts of climate change on Cyprus' forests and specifically the more intense droughts and very high temperatures during summer, can make fires even more destructive. Urbanization increases the fire hazard due to the abandonment of agricultural land and consequently the increase of flammable forest vegetation in case of fires. Figure 8-3 testifies the increasing trend of fires for the period 2001 to 2010.

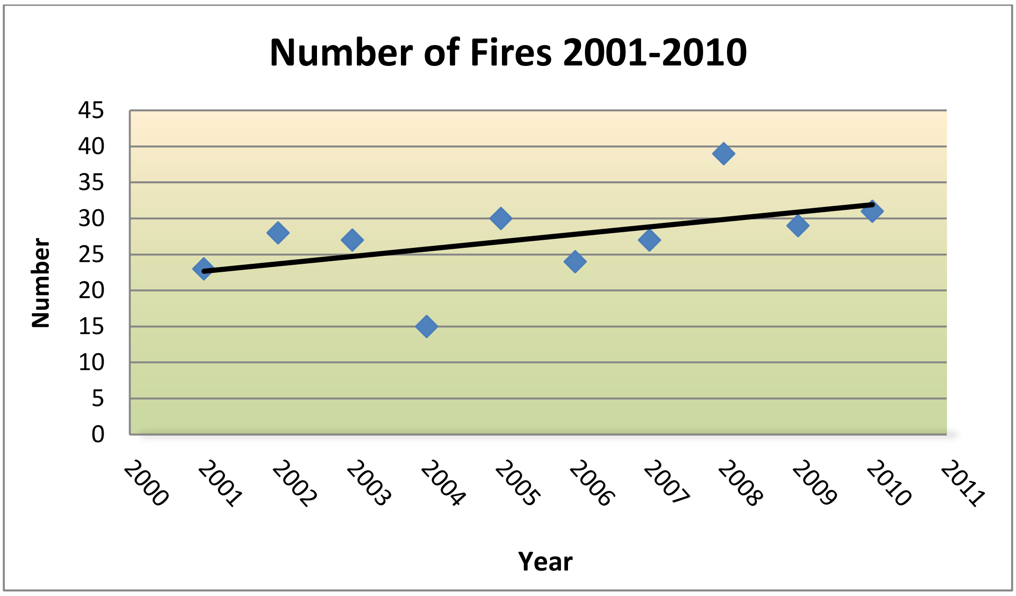


Figure 8-3: Trend of fires in Cyprus for the period 2001 – 2010

Source: Department of Forests, 2011a

8.3.3 Floods, wind throws and storm damages

Floods, wind throws and storm damages are most relevant in central Europe as well as in western and northern Europe. Forest damage by wind and snow are a continuing cause of economic loss in forestry throughout Europe. In some climate change scenarios wind throws increase in northern Europe and decreases in the Mediterranean region. The increase in wind throws in northern Europe is largest in winter and early spring (Lindner *et al.,* 2008).

The economic impact of wind damages is particularly severe in managed forests because of the reduction in the yield of recoverable timber, the increased costs of unscheduled thinning and clear-cutting, and resulting problems in forestry planning. Furthermore, broken and uprooted trees left in forest can lead to detrimental insect attacks on the remaining trees because of an increase in the amount of available breeding material. Despite the great severity of the particular climate change impact on forests, there are no available data for wind throws and storm damages in Cyprus.

Flooding is more harmful if it occurs during the growing season than if it occurs during the dormant season of plants. Plant responses to flooding during the growing season include injury, inhibition of seed germination, changes in plant anatomy and promotion of early senescence and mortality. Trees are most vulnerable to the effects of flooding in late spring, just after the first flush of growth (Lindner et al., 2008).

Extreme flooding events are expected to occur more frequently as a consequence of climate change. Global circulation models predict that it is very likely that higher amounts of precipitation will occur in northern Europe, especially during winter and spring, considerably increasing the risk of flooding in Central and Northern Europe. The number of rain days is projected to decrease, but the number of days with heavy rain events is projected to increase. This change is leading to more summer droughts as well as more extreme flooding events during summer. In Cyprus, floods have recorded an increase during the last decades especially those occurring in urban areas. However this cannot be attributed directly to climate changes but most possibly to the reduction of floodplains due to urban development.

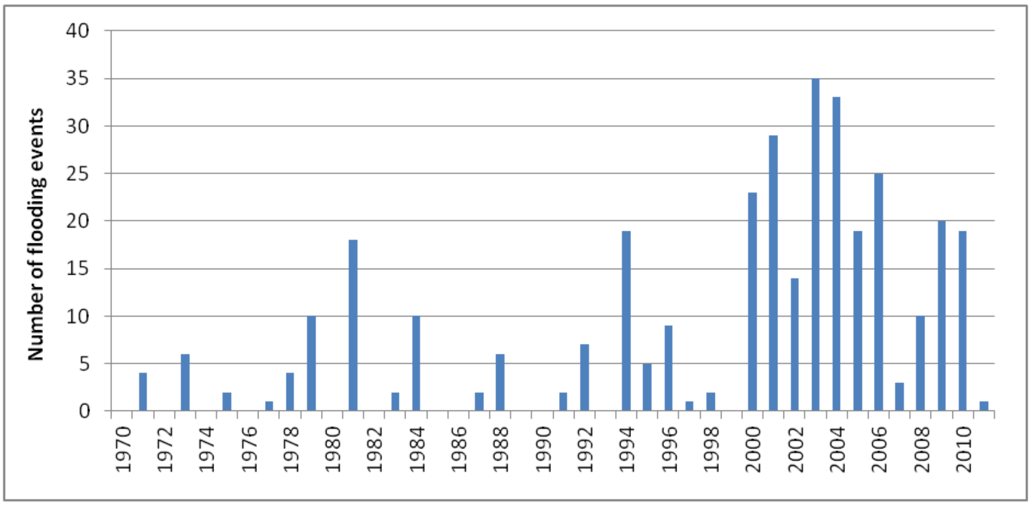


Figure 8-4: Number of recorded flooding events in Cyprus for the period 1970-2011

Source: WDD, 2011

8.3.4 Forest growth

Many aspects of projected climate change will likely affect forest growth and productivity such as increases in air pollution, increases in temperature, and changes in precipitation. Warming temperatures could increase the length of the growing season. However, warming could also shift the geographic ranges of some tree species northward or to higher altitudes or could even cause their extinction if conditions in their current geographic range are no longer suitable. For example, species that currently exist only on mountaintops may die out as the climate warms since they cannot move to a higher altitude (EPA, 2012).

During hot spells, photosynthesis decreases and biomass growth and yield are expected to decline. Even drought-adapted ecosystems are influenced by increased heat which can lead to reduced plant growth and primary productivity as well as to altered plant recruitment (Linder *et al.,* 2010).

Precipitation is a factor with a significant effect on forests' growth. Any changes in the frequency and availability of precipitation, affects the plant growth and the forest cover in particular. In Cyprus, in the last 30-year period, precipitation decreased by almost 17% in comparison with the period 1901-1930 while temperature increased at a rate of 0.01°C per year.

Atmospheric CO_2 is a substrate for plant photosynthesis. Therefore, rising concentrations of CO_2 in the atmosphere is believed to act as a fertilizer and increase photosynthesis rate. Tree growth rate might not increase proportionally with increase in photosynthesis because other factors (such as nutrient availability) may become more important, thus limiting the ability of trees to increase their growth rates, particularly in natural ecosystems (Lindner *et al.,* 2008).

The chemical atmospheric environment affecting tree growth include tropospheric and ground-level concentrations of ozone, which may increase drought stress in trees and reduce tree biomass under current ambient compared to pre-industrial concentrations. Also atmospheric nitrogen deposition has been a major factor influencing forest growth and other ecosystem characteristics over the last decades. Ozone and nitrogen deposition affect tree physiology, carbon allocation and plant interactions, resulting in complex interactions with other climatic impact factors such as drought (Lindner *et al.,* 2008).

However, the available data for Cyprus is limited not allowing for a correlation with climate changes to be made. Cyprus, has recently joined the ICP international program on the assessment and monitoring of air pollution effects on forests from which more concrete data are expected to be provided.

8.4 Vulnerability assessement

In this section, the vulnerability of forests is assessed in terms of their sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which forests are affected by climate changes, exposure is the degree to which forests are exposed to climate changes and their impacts while the adaptive capacity is defined by the ability of forests to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The indicators used for the assessment of sensitivity, exposure and adaptive capacity of Cyprus forests to climate change impacts are summarized in Table 8-6.

Table 8-6: Indicators used for the vulnerability assessment of climate change impacts on the forests of Cyprus

Vulnerability Variable	Selected Indicators
Dieback of tree species, insects attacks and diseases	
Sensitivity	– Species affected by drought – Species affected by pest and diseases – Proportion of trees with insect occurrence – Pests affecting tree species – Area with drought problems and distress – % of species within Cyprus threatened – Distribution of threatened species
Exposure	– Forest areas exposed to increased temperatures – Forest areas exposed to decreased precipitation – Frequency and intensity of droughts
Adaptive capacity	– Monitoring – Dead trees removal – Control of insect populations – Irrigation – Thinning – Restriction of afforestation/refostation – Limit timber
Fires	
Sensitivity	– Climatic factors (temperature, wind, humidity) – Presence of flammable vegetation – Topography – Urbanization factor – Fire risk in Cyprus – % of species within Cyprus threatened – Distribution of threatened species
Exposure	– Number of fires, burnt areas, fire size – Fire Weather Index – Fire season (months)

Vulnerability Variable	Selected Indicators
Adaptive capacity	– Fire Prevention measures – Fire Pre-suppression measures – Suppression measures – Increase water supply points – Early Warning System – Increase Alert and Readiness – Restoration of burnt areas
Floods, wind throws and storm damages	
Sensitivity	– Age of species – Slopes – Height of vegetation
Exposure	– Forest areas with risk to be exposed or exposed to floods
Adaptive capacity	– Flood Risk Management Plans in progress – Need for adaptation measures
Forest growth and air pollution	
Sensitivity	– Sensitive species to air pollution (ozon, nutrient nitrogen, acidity etc) * – Sensitive species to increased temperature and decreased precipitation *
Exposure	– Concentration of ozone in forest areas – Exceedances of critical loads of nutrient nitrogen and acidity – Forest areas exposed to increased temperatures – Forest areas exposed to decreased precipitation – Frequency and intensity of droughts
Adaptive capacity	– Monitoring of the effect of air pollution to forest growth

*There were no data regarding this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability is assessed for each of the impact categories presented in Section 8.3:

1. Dieback of tree species, insect attacks and diseases
2. Fires
3. Floods, wind throws and storm damages
4. Forest growth

The vulnerability of forest ecosystems varies substantially as it is related to the different rate and magnitude of climate change in different parts of Cyprus due to the variability of the air pollution levels, altitude, temperature, rainfall variations and meteorological conditions (e.g. wind, moisture), local geomorphology and soil characteristics.

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability. In case additional data are provided by the competent authorities of Cyprus, the vulnerability of the sector could be re-assessed.

8.4.1 Dieback of tree species, insects attacks and diseases

8.4.1.1 Assessment of sensitivity and exposure

Sensitivity

The prolonged drought during the period 2005-2008, had a significant effect on a large number of forest species, including Pinus brutia, Pinus halepensis, Pinus pinea, Acacia, Cypress, Arbutus andrachne, Quercus alnifolia, Crataecus azarolus, and Olea europaea (Ioannou, 2008; Cyprus Institute, 2011). In Cyprus, the impact of droughts is significant for the health of the forest ecosystem, while an increase of the temperature only for 1-2 °C might be the end of the species of Pinus nigra at the top of Troodos mountains.

Additionally, the drought period 2005 – 2008 resulted to the necrosis of a significant area of pines and cypress in Stavrovouni forest in Larnaca and of several trees of the Stone Pine species (Pinus pinea) –which are very demanding in soil moisture- in the Rizoelia National

Forest Park, while in 2007 thousands trees of Brutia Pine species (Pinus brutia) and Stone Pine (Pinus pinea) dried up due to the impact of insects (Department of Forests, 2011a; Department of Forests, 2011b).

The study on the dieback of Cedrus brevifolia growing in Cyprus which is limited to the Tripylos area (Cedars valley), in the Paphos forest, showed that the increased incidents of dieback during the period 1998-2001 are attributed to the adverse environmental conditions that prevailed in Cyprus and particularly the decrease in rainfall and the increase in air temperature (Christou et al., 2001).

According to Table 8-7, the dieback incidents of trees during the period 2007-2008 were more intense in the forest regions of Nicosia, Larnaca and Famagusta (16%) and in Troodos (7%).

Table 8-7: Dieback Inventory Summary at state forests of Cyprus (period 2007-2008)

Forest Region	Total Forest Covered Area (ha)	Area with Serious drought Problems (ha)	Area with Serious Distress and low drought (ha)	Total Forest Area with Problems (columns 3+4) (ha)	Percentage (%)
Paphos	69,386	70	1,307	1,377	1.98
Troodos	33,760	453	1,835	2,287	6.78
Nicosia, Larnaca, Famagusta	18,422	1,479	1,474	2,953	16.03
Forestry College (Limassol)	2,342	0	16	16	0.68
Total	**123,911**	**2,002**	**4,631**	**6,633**	**6.37**

Source: Department of Forests, 2009a

A large number of tree species are affected by indigenous insects. The dominant forest pests affecting both naturally regenerating forests and planted forests in Cyprus are presented in Table 8-8.

Table 8-8: Forest pests (indigenous insects) which affect natural regenerating and planted forests of Cyprus

Insects	Affected tree species
Lymantria dispar Linnaeus	Broadleaved trees, oak (Quercus infectoria ssp. Veneris), golden oak (Quercus alnifolia), strawberry tree (Arbutus andrachne), terebinth (Pistacia terebinthus)
Orthotomicus erosus	Calabrian pine (Pinus brutia), Black pine (Pinus Nigra ssp. Pallasiana)

Phloeosinus armatus	Cypress tree (Cupressus Sempervirens), Gold crest or Monterey Cypress (Cupressus macrocarpa Hartw)
Thaumetopoea wilkinsoni	Calabrian pine (Pinus brutia), P. Canariensis, P. Halepensis And the hybrid P. Brutia x P. Halepensis.Thaumetopoea wilkinsonii
Tomicus destruens	Pinus brutia
Tomicus piniperda	Calabrian pine (Pinus brutia)
Tomicus minor Hartig	Pinus brutia, Pinus nigra Var. Caramanica

Source: FAO, 2008

In 2010, the proportion of trees in Cyprus with insect occurrence was at most cases 75-100%, as shown in Figure 8-5.

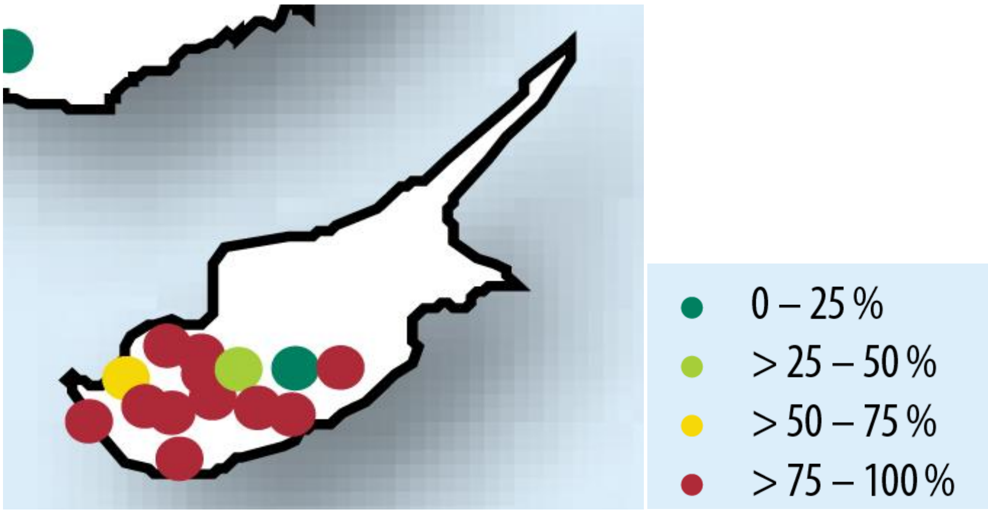


Figure 8-5: Proportion of trees per plot with insect occurrence in 2010

Source: LRTAP/EWF, 2011

The recorded outbreaks of insects that affected Pinus bruttia's health and vitality are shown on Table 8-9.

Table 8-9: Impacts of insect outbreaks to Pinus bruttia

Description / name	Tree species or genera affected (scientific name)	Year(s) of latest outbreak	Area affected (1000 hectares)	If cyclic, approx. cycle (years)
Thaumetopoea wilkinsonii	*Pinus brutia*	2007	8.1	Every year
Leucaspis knemion	*Pinus brutia*	2006 2007	0.2 0.2	x

Source: FRA, 2010

In Table 8-10, the area, density and distribution of the main tree and other woody forest species threatened by drought, desertification, pests and diseases as well as the range of threat within Cyprus, are presented.

Table 8-10: Main tree and other woody forest species considered to be threaten by drought, desertification and pests in all or part of their range in Cyprus

Species (scientific names)	Area (ha) of species, natural distribution	Average number of tree per hectare	Distribution in Cyprus	Type of threat	Threat Category*		
					High	Medium	Low
Cedrus brevifolia (tree)	367	75	Local	Drought & desertification Pests and diseases		X	
Juniperus excels (tree)	643	32	Local	Drought & desertification		X	
Pinus nigra ssp. pallasiana (tree)	4,970	n.a.	Local	Pests and diseases		X	
Juniperus foetidissima (tree)	72.7	n.a.	Local	Drought & desertification		X	
Quercus infectoria ssp. veneris (tree)	354.7	n.a.	Widespread	Drought & desertification Pests and diseases	X		
Cupressus sempervirens (tree)	450	n.a.	Widespread	Drought & desertification Pests and diseases			X
Arbutus unedo (shrub)	1.5	53	Local	Drought & desertification	X		
Phillyrea latifolia (shrub)	596	8.4	Rare	Drought & desertification	X		

Species (scientific names)	Area (ha) of species, natural distribution	Average number of tree per hectare	Distribution in Cyprus	Type of threat	Threat Category*		
					High	Medium	Low
Viburnum tinus ssp. tinus (shrub)	17	60	Local	Drought & desertification	X		

**Threat categories: High – threatened throughout species range within Cyprus, Medium – threatened in at least 50% of range within country, Low-threatened in less than 50% of range within country.*

Source: Department of Forests, 2011a

As it can be seen from the table above, four out of nine main forest trees and shrubs are considered highly threatened by drought, desertification, pests and diseases.

Considering the above, the sensitivity of Cyprus' forests to increased diebacks and insect outbreaks is characterized as **high to very high**.

Exposure

Rainfall is geographically unevenly distributed, with maximum precipitation falling on the island's two mountainous masses where the two main state forests are found whereas minimum precipitation is observed in the eastern plain and the coastal areas. The main bulk of precipitation (about 80% of the total) falls during November and March, while the period from May to September is a biologically dry period. The areas most exposed to low precipitation, high temperatures and drought conditions especially during summer are the coastal areas (such as Paphos, Limassol, Larnaca and Famagusta) while the mountain areas (Troodos) are characterized by higher precipitation and lower temperature. However, it must be mentioned that the area of Troodos mountains where major state forests are located is featured by higher annual precipitation decreases for the period of 1917 to 2000 comparatively to the rest free part of Cyprus (Figure 8-6).

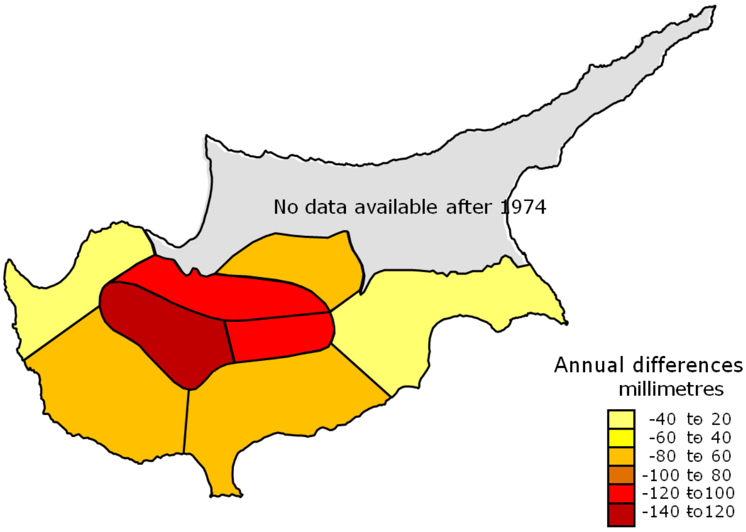


Figure 8-6: Changes in annual and monthly mean precipitation at regional scale 1971-2000 mean minus 1917-1970 mean in millimeters

Source: Meteorological service of Cyprus

As it can be seen from Figure 8-7, the areas most exposed to increases in mean temperatures when comparing the periods 2001-2008 and 1981-1990, are the western part of Cyprus between Paphos and Polis Chrysochous (up to 3.0-3.5 ^{o}C increase) and to a lesser extend the wider area of Larnaca and Famagusta (up to 1.5-2.0 ^{o}C increase). These areas are characterized mainly by maquis and garique vegetation.

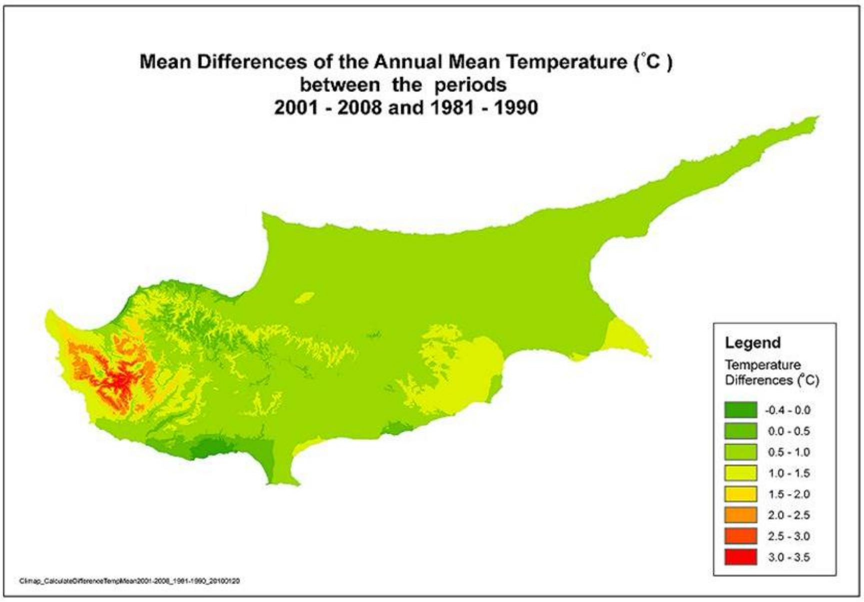


Figure 8-7: Mean differences of the annual mean temperature of Cyprus between the periods 2001-2008 and 1981-1990

Source: Meteorological Service of Cyprus

The Standardized Precipitation Index, which provides a quantitative definition of drought, was computed for the case of Cyprus for the period 1970/71 - 2010/2011. The past 40 years have been marked by three extreme drought years, with an SPI below -2 (1972/73, 1990/91, 2007/08). There were also three years of moderate droughts (1989/90, 1999/00, 2005/06 and 12 years of mild drought (Cyprus Institute, 2011). From the SPI values it can be seen that drought events appear in Cyprus with great frequency while there are some years of quite intense droughts.

Considering the above, the exposure of Cyprus' forests to increased temperatures, decreased precipitation and droughts causing diebacks and insect outbreaks is characterized as **high to very high**.

8.4.1.2 Assessment of adaptive capacity

The Department of Forests in Cyprus has taken action considering the implications of droughts and high temperatures and prepared a "Short-term Action Plan for the Confrontation of the Implications of Drought in Cyprus state forests (2009-2010)". The Plan consists of 8 sectors which contain 20 measures and 35 actions in total.

The aims of Cyprus Short-term Action Plan are summarized as follows: (i) The planning of measures and infrastructure projects with a defined implementation schedule, so that the Cyprus Forestry could react quickly to any negative effects of drought, (ii) The creation of infrastructure projects addressing the impacts of climate change, as anticipated by various scenarios on climate change, (iii) To provide the aid for a future medium – term strategic planning for adaptation of the Cypriot forestry to climate change.

The measures and actions include all those projects and activities that should be planned and implemented by the Forestry Department in order to mitigate the adverse impacts of drought in state forests. The measures address the dieback of tree species, insect attacks, biodiversity loss as well as fires. Although the draft contains all the actions to be undertaken / implemented the years 2009 -2010, the Plan has flexibility and can be adjusted depending on the progress of drought and the new data that may arise. Also, some of the actions will be implemented gradually until 2013 (Department of Forests, 2009b). Next, the plan's measures for combating dieback of forests and insect attacks as well as for the protection of biodiversity are presented in brief.

Table 8-11: Dieback and insect attack prevention and reduction measures, Short-term Action Plan

Measure	Dieback	Insect attacks	Biodiversity	Comments
Systematic monitoring of the problems caused by drought with annual recording of forest damage	X			First year of implementation: 2007-2008
Exploitation of the gathered information	X	X		Monitoring of insect attacks

Measure	Dieback	Insect attacks	Biodiversity	Comments
from the implementation of the program «ICP - Forests»				Collection of temperature and rain data for monitoring risk for dieback
Install surface monitoring of the impact of the thinning in forest clusters	X	X		Increase in soil moisture Control spreading of insects and avoid population build-up
Removal of dead trees		X		Control of insect populations
Control of harmful insect populations		X		Insect traps
Irrigation program	X			Apply irrigation at stressed trees
Thinning program	X	X		Increase in soil moisture Control spreading of insects and avoid population build-up
Cultivating care	X			Appropriate ploughing to retain water in roots
Restriction of reforestation and afforestation programs	X			Decrease competition of water demand between trees Increase water uptake per tree Implementation in areas affected by water scarcity (excl. burnt areas, highways, cities)
Reduce the production of new forest planting on forest nurseries			X	Emphasis on dry-resistant species
Storage genetic propagation material in forest nurseries			X	
Limit timber			X	Exercise timber only in areas not affected by drought
Installation program of watering troughs in forests for covering fauna needs			X	
Utilization of the water resources/boreholes in the state forest			X	
Cleaning programme of natural springs in forests			X	

Measure	Dieback	Insect attacks	Biodiversity	Comments
Awareness raising	X	X	X	

Source: Department of Forests, 2009b

Apart from clean forest practices for controlling pest populations, natural controls including the introduction of insect parasites and predators as well as aerial and ground application of chemical and biological insecticides are widely used in Cyprus. In recent years only biological insecticides have been used in Cyprus to prevent defoliation and the annoying effects of the pests (Department of Forests).

Last but not least, the Forest Department taking into consideration the serious problems caused by droughts in the Cyprus Forestry and the negative impact climate change is expected to have on forests, has decided to prepare a "Mid Term Strategic Plan for the Adaptation of Cypriot Forestry to Climate Change" (Department of Forestry, 2009b).

Despite the numerous measures that are implemented in Cyprus for combating dieback of forests and insect attacks as well as for the protection of biodiversity, the effect can only be alleviated but not eliminated. Thus, the adaptive capacity of Cyprus is characterized as **limited to moderate**.

8.4.2 Fires

8.4.2.1 Assessment of sensitivity and exposure

Sensitivity

Forests in Cyprus are sensitive to fires because of their composition which is dominated by flammable vegetation and the topography of the forested areas, which is mostly mountainous. Moreover, urbanization increases the fire hazard because agricultural land is abandoned resulting in an increase of flammable forest vegetation and the decrease of human activity in the countryside as well as the availability of human resources in case of fires (Department of Forests).

As it can be seen from Figure 8-8, the fire risk of Cyprus forests is “very high” at all the main state forests of Troodos and Pentadactylos and “high” at maquis and garique vegetation areas found at Troodos and Pentadactylos as well as southern of Troodos.

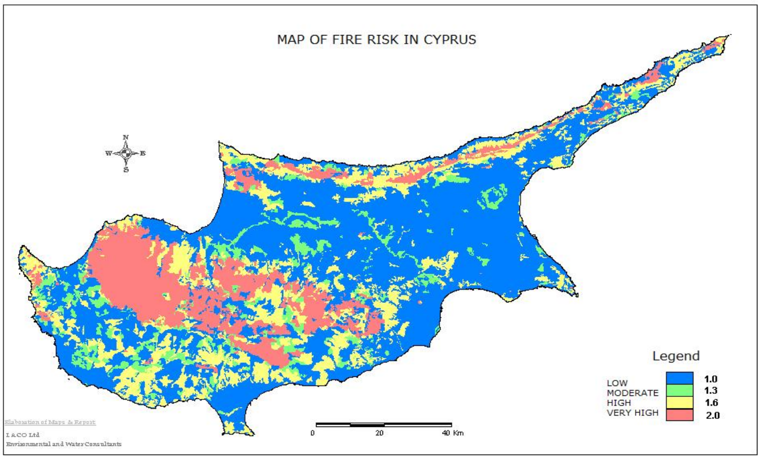


Figure 8-8: Map of fire risk in Cyprus

Source: Environment Service, 2007

The area, density and distribution of the main forest tree and shrub species that are threatened by forest fires as well as the range of threat within Cyprus, are presented in Table 8-12.

Table 8-12: Main tree and other woody forest species considered to be threatened by forest fires in all or part of their range in Cyprus

Species (scientific names)	Area (ha) of species, natural distribution	Average number of tree per hectare	Distribution in Cyprus	Threat Category*		
				High	Medium	Low
Cedrus brevifolia (tree)	367	75	Local		X	
Juniperus excels (tree)	643	32	Local		X	
Pinus nigra ssp. pallasiana (tree)	4,970	n.a.	Local		X	
Juniperus foetidissima (tree)	72.7	n.a.	Local		X	
Quercus infectoria ssp. veneris (tree)	354.7	n.a.	Widespread	X		
Cupressus sempervirens (tree)	450	n.a.	Widespread			X
Arbutus unedo (shrub)	1.5	53	Local	X		
Phillyrea latifolia (shrub)	596	8.4	Rare	X		

Species (scientific names)	Area (ha) of species, natural distribution	Average number of tree per hectare	Distribution in Cyprus	Threat Category*		
				High	Medium	Low
Viburnum tinus ssp. tinus (shrub)	17	60	Local	X		

**Threat categories: High – threatened throughout species range within Cyprus, Medium – threatened in at least 50% of range within country, Low-threatened in less than 50% of range within country.*

Source: Department of Forests, 2011a

As it can be seen from the table above, four out of nine main forest trees and shrubs in Cyprus are considered highly threatened by fires.

Considering the above, the sensitivity of Cyprus' forests to fires is characterized as **high to very high**.

Exposure

Forests in Cyprus, like all Mediterranean forests, are exposed to fires especially during the summer period because of the climatic conditions. Normally the fire season starts in May and ends in October, but occasionally it starts in April and is extended up to November (Figure 8-9). Various climatic agents like temperature, relative humidity, and precipitation affect fuel moisture. The long, hot and dry summers that last from May until October convert the pine into a dry and highly inflammable fuel mass. During the fire season the temperature fluctuates from 30° to 44°C increasing the risk of ignition to very high levels. The relative humidity, which affects considerably the fire environment, ranges between 30-65%. Rainfall during the fire season is very low and ranges between 0-50mm. Wind is a dominant factor of fire behaviour. It is one of the hardest elements to predict due to variability of wind speed and direction and the influences of topography, vegetation, and local conditions. Winds during the fire season are mostly northwesterly or northerly (IFFN, 2005).

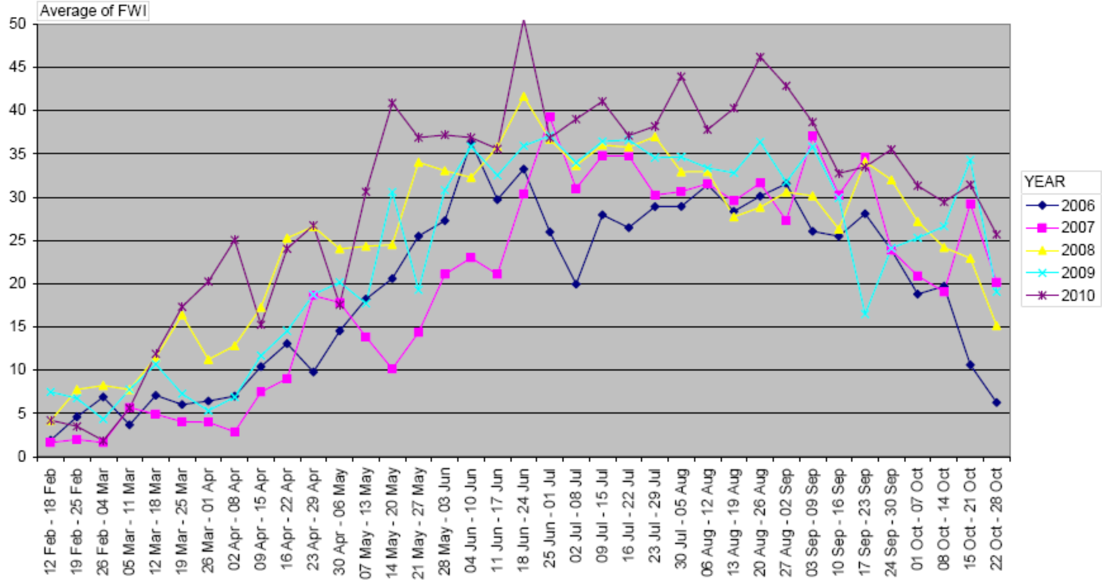


Figure 8-9: Fire danger trends in Cyprus for the period February-October 2006-2010 (weekly averages)

Source: JRC-IES, 2011

Throughout the period 2000-2010, 2,281 fires were recorded in Cyprus, while the total burnt area amounted to 31,385 hectares, 47% (14,654 hectares) of the burnt area being forests and other wooded land. The largest number of forest fires in Cyprus during the last decade was recorded in 2003 while the year with the greatest severity in forest fires in terms of total area burnt was 2007. The number of fires and burnt area for the decade 2000-2010 are presented in the following table.

Table 8-13: Number of forest fires and burnt areas in Cyprus, 2000-2010

Year	Number of fires	Burnt area (ha)	
		Total	Forest and other wooded land
2000	285	8,034	2,552
2001	299	4,830	778
2002	243	2,196	166
2003	427	2,349	921
2004	221	1,218	667
2005	185	1,838	962
2006	172	1,160	888
2007	111	4,483	3,704
2008	114	2,392	1,997
2009	91	885	460
2010	133	2,000	1,559

Year	Number of fires	Burnt area (ha)	
		Total	Forest and other wooded land
Total	**2281**	**31,385**	**14,654**

Source: JRC-IES, 2011

The trends regarding both the number of fires and burnt areas over the last 10 years (2000-2010) are shown in Figure 8-10.

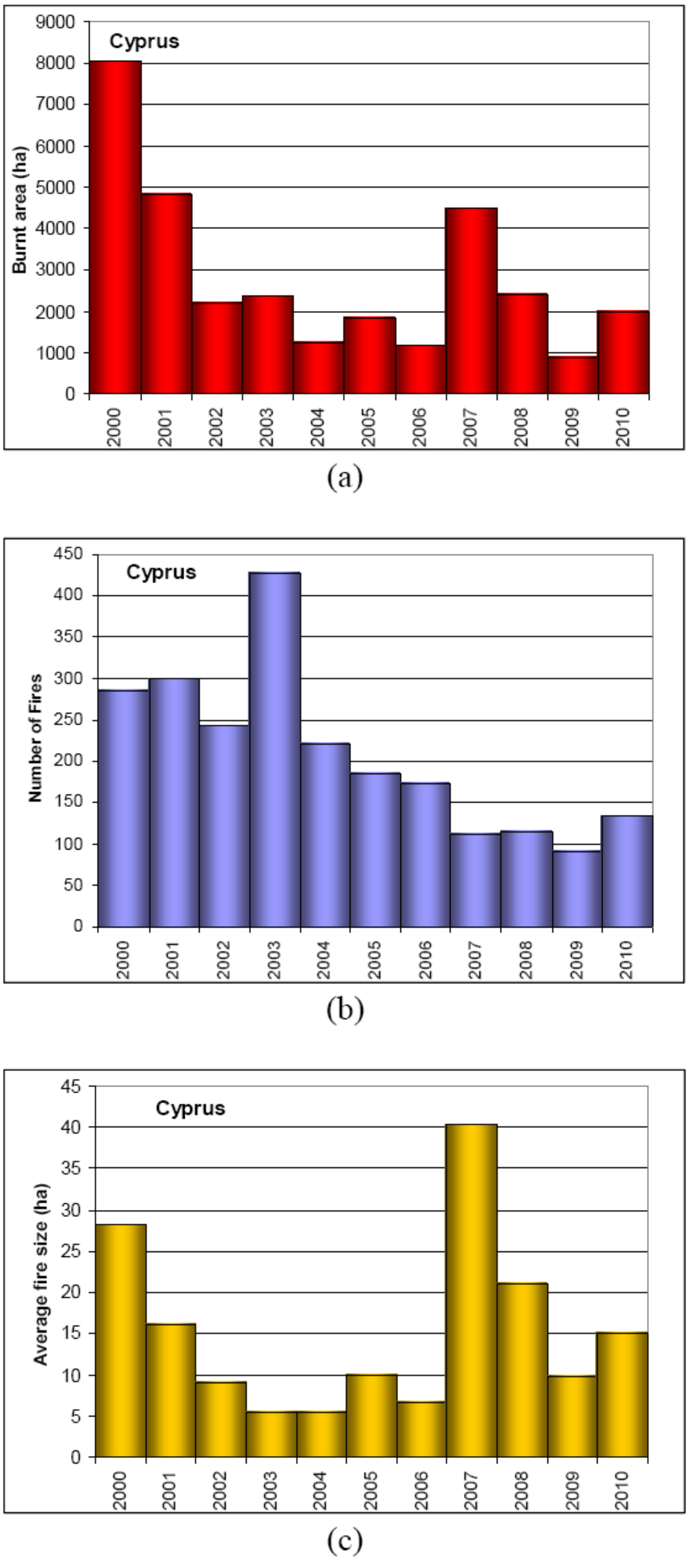


Figure 8-10: (a) Burnt areas, (b) Number of fires and (c) Average fire size in Cyprus from 2000 to 2010

Source: JRC-IES, 2011

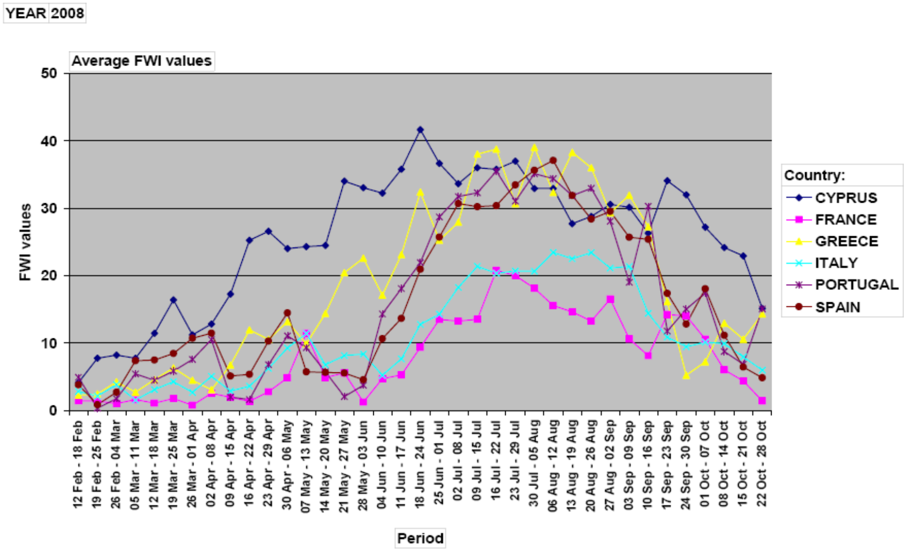
According to data obtained from the Department of Forests in Cyprus, during the decade 2001-2010 the number of fire outbreaks within the state forest land was 273 and the burned state forest land was estimated at 1,280 hectares. As it can be seen, the number of fires in state forests and area burnt are considerable lower than the number of total forest fires and area burnt. The number of state forest fires and burnt area for the decade 2001-2010 are presented in the following table.

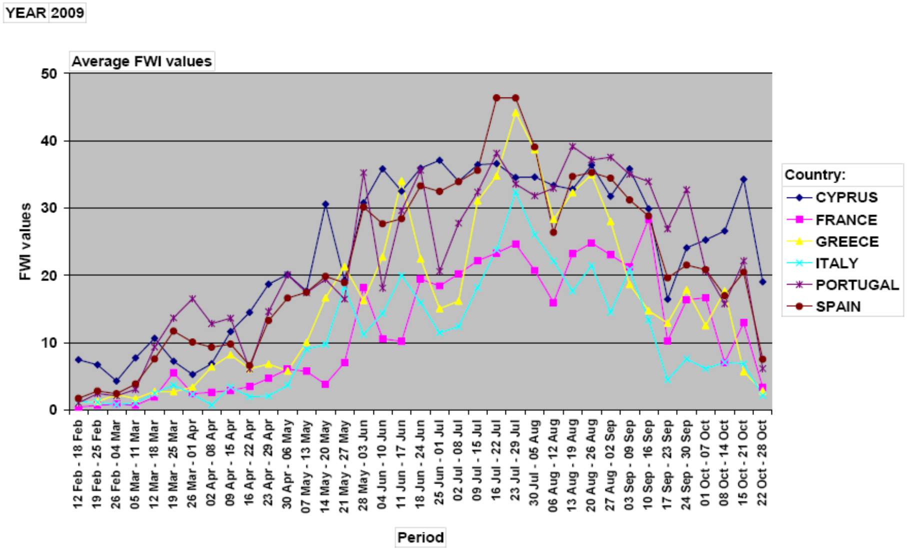
Table 8-14: State forest fires for the decade 2001 – 2010

Year	Number of State forest fires	State forest burnt area (ha)
2001	23	380
2002	28	20
2003	27	11
2004	15	14
2005	30	43
2006	24	112
2007	27	619
2008	39	13
2009	29	5
2010	31	63
Total	**273**	**1,280**

Source: Department of Forests

As it can be seen from Figure 8-11, Cyprus Fire Weather Index (FWI) values for the period 2008-2010 are among the highest in comparison with the other European countries located in the Mediterranean.





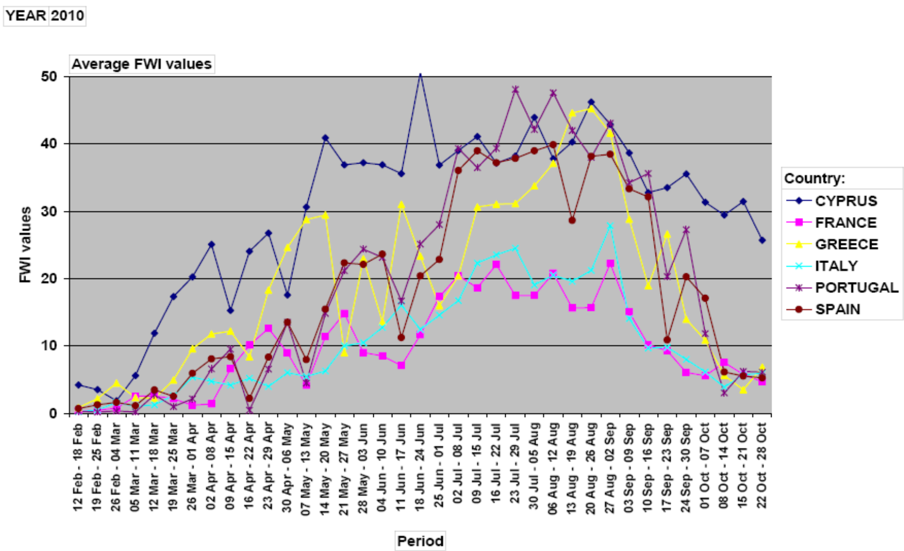


Figure 8-11: Fire danger trends 2008-2010 in EU Mediterranean countries (CY, FR, GR, IT, PT, ES)

Source: JRC-IES, 2011

Considering the above, the exposure of Cyprus' forests to fires is characterized as **high to very high**.

8.4.2.2 Assessment of adaptive capacity

Several measures are taken by the Forestry Department of Cyprus aiming to eliminate forest fires. Particularly, the (a) prevention, (b) pre-suppression, (c) detection and suppression measures are presented as follows:

(A) Fire Prevention measures. Fire Prevention measures include all actions and measures aimed at reducing or eliminating the potential for a fire outbreak. The main prevention measures taken are the following (Boustras et al., 2008):
Law enforcement: The Forest Law prohibits the lighting of fires and throwing of burning cigarette ends or matches in the State forest or within a radius of one kilometer from the State forests boundaries. Offenders are liable to imprisonment or to a fine or to both such sentences.

Information campaigns: An information campaign aiming at educating the public, particularly young people is organized annually. Moreover, during the fire season messages are broadcasted through radio and television, to raise public awareness.

Picnic and camping sites: In order to avoid the risk of uncontrolled fire ignitions by people visiting forested areas for recreation purposes, numerous picnic and camping sites had been established.

Patrolling: Throughout the fire season, regular patrols are organized, mostly along the boundaries of the State forest where most fires start. The aims of patrols are public information, enforcement of the law and detection and timely intervention in case of fire.

Fire danger mapping: Fire danger mapping is done on a daily basis, using meteorological data that are collected from a network of automatic weather stations installed for this purpose in different locations all over Cyprus.

(B) Fire Pre-suppression measures: Fire Pre-suppression measures include all actions and measures aimed at reducing the likelihood of spread of a potential fire and at facilitating the efforts of effective fire suppression. The main pre-suppression measures taken are the following (Department of Forests, 2012):

Fire breaks: Fire breaks are designed to interrupt the continuity of fuels. In case of fire, the fire breaks normally will slow the rate of spread, thus enabling the ground fire fighting forces to reach the head of the fire and suppress it easily and with relative safety.

Forest roads: Within State forests there is a good road network. Forest roads are necessary and extremely important both for forest management and fire protection purposes.

Forest telecommunications: The Forestry Department maintains its own independent telephone network, mainly used for the coordination of prevention, detection and suppression activities. This network includes repeaters and radiotelephones placed in all forest stations, fire lookout stations, fire engines and personnel vehicles. In addition, all forest officers are equipped with portable radiotelephones.

Forest Stations: Forest stations are located in forested areas all over the island and are manned by both permanent and seasonal staff.

Silvicultural treatments: Silvicultural treatments aim at reducing the risk of ignition and spreading rate of fires. These include pruning, thinning and clearing of vegetation along forest and intercity roads, as well as, in areas where there is a high risk of fire ignition.
Detection and reporting of forest fires: Include all actions and measures aimed at forming a mechanism able to quickly detect, locate and report a potential fire, enhancing timely attack and extinction. The main detection and reporting measures taken are the following:

Fire lookout stations: Fire lookout stations are placed in strategic locations, usually at the top of mountains. During the fire season these stations are staffed with experienced observers and enable continues monitoring for potential fires on a 24-hour basis.

Automatic fire detection system: For the systematic monitoring for potential fires within the Akamas National Forest Park, an Automatic fire detection system had been installed. This system was installed on a pilot basis with the financial support of the European Union.

Reporting of forest fires: The public may report the existence of forest fires through the telephone number 1407, which operates free of charge on a 24-hour basis.

(C) Suppression measures: The suppression of forest fires is a complex, difficult and dangerous work that requires specialized knowledge, education and organization. Suppression includes all actions and measures aimed at facilitating rapid intervention and effective suppression of a potential fire. The main suppression measures taken are the following (Department of Forests, 2012):

Forest fire fighting task force: At the beginning of every fire season, the body of forest fire fighting task force is organized. Forest fire fighters, split-up into groups of 6-15 individuals and are then positioned into different forest stations.

Stand-by of forest officers: Throughout the fire season, a number of forest officers remain on duty on a rotation basis. In case of a fire, they lead the forest fire fighting task force to the scene of the fire and organize and coordinate the suppression operation.

The Cyprus Forestry College: The lecturers, students and forest fire fighters of the Cyprus Forestry College, form a well-organized firefighting force. Similarly to forest officers, the personnel of the college remain on duty on a rotation basis during the fire season.

Fire engines: The Department of Forests has a significant number of fire engines which are manned by experienced forest fire fighters. These fire engines are distributed to the different forest stations.

Personnel vehicles: Cross country vehicles are used in case of fire for the transfer of forest officers and the forest fire fighting task force.

Tractors: The Department of Forests owns a number of tractors (bulldozers). These, are mainly used for the construction and maintenance of forest roads and fire breaks. In case of a fire incident they are used in active fire fighting through the construction of fire breaks.

Warehouses: In almost all forest stations, warehouses can be found in which the necessary fire fighting tools and equipment are stored.

Fire protection systems: Fire protection systems are installed in forested areas where large numbers of people may concentrate, such as picnic and camping sites. These systems consist of a number of fire nests which are continually supplied with water from existing pipes or water tanks (water reservoirs).

Water tanks and hydrants: In case of a forest fire, it is of great importance the fast refilling of the fire engines with water. For this purpose, a network of water tanks is constructed in most forested areas and hydrants and water valves are installed.

Heliports: Numerous heliports can be found within or near forested areas. These, in case of emergency can be used for the landing of helicopters transferring fire fighters, supplies and people injured during fire fighting.

Aerial means: Fighting of fires using aerial means such as aeroplanes and helicopters has been practiced with good results during the last decade.

Cooperation with other agencies and the public: There is continuous cooperation between the Department of Forests, who has the full legal, administrative and technical responsibility for extinguishing forest fires, and other Government Services which are involved in the fighting, such as the Fire Service, the District Administration, the Police, the Civil Defense, the Game Fund and the National Guard. This cooperation aims at the best possible organization and efficient fire fighting, primarily of large scale fires in our island. There is also a close collaboration with the Civil Aviation, the United Nations Force, the British Base in Cyprus, and Municipal Authorities.

As a result of the measures mentioned above it was managed to reduce both the time of intervention and the area burnt each year. The average time of response during fire incidents for the period 2000 - 2003 was only 12.5 minutes.

In addition, the Short-term Action Plan for the Confrontation of the Implications of Drought in Cyprus state forests (2009-2010), foresees a number of measures for the protection from fires:

- Measure 16: Forestry Measures – Pruning and cleaning of herbaceous and woody vegetation along roads in order to reduce the risk of ignition and the spreading rate of forest fires
- Measure 17: Increase in Water Supply Points for Use by Fire Helicopters
- Measure 18: Development of Early Warning System for Forest Fire Outbreak and Expansion for all state forests
- Measure 19: Alert and readiness for fire protection

However, it must be mentioned that in contrast to state forests and OWL for which the Department of Forests undertakes the full responsibility for their protection from fires, in private forests and OWL, which account for the 50% of the forest and OWL area of the island, there is no infrastructure such us fire breaks, forest roads, water tanks, forest stations etc, making the protection of these areas from fires insufficient.

Economic incentives

The EU through its Regulation (EEC) 2158/92, which refers to the protection of Community forests against fires, finances a series of actions aiming at the reduction of the number of fires and the burnt areas. The funded actions include infrastructure for fire fighting and improvement of degraded forests.

Moreover, in the framework of the Rural Development Programme 2007-2013 of Cyprus, economic incentives are provided to individuals through the Measure 2.5 "Protection of forests from fires and reforestation areas". The main purpose of the measure is to improve the existing protection system of forests and other forest areas from fire as well as the restoration of burned areas. The measure includes the following two actions: (i) fire prevention, (ii) reforestation of burnt areas.

(i) Fire prevention. This action is limited in prevention measures and foresees the provision of financial support for the construction / installation of fire protection infrastructure, maintenance of fire belts, and the development and improvement of fire detection and communication equipment.

(ii) Reforestation of burnt areas. This action involves the rehabilitation of burned forest areas. This measure enhances the protection of private forests which are not covered by the national forest protection programme.

Despite the great efforts and the good results of recent years, the problem of fires still exists and will always constitute a permanent threat for the forests of Cyprus. Thus, the adaptive capacity of Cyprus forests to fires can be characterized as **moderate.**

8.4.3 Floods, wind throws and storm damages

8.4.3.1 Assessment of sensitivity and exposure

Sensitivity

The factors affecting the sensitivity of forests to floods, are the slope of the area, the age of the plant species, their anatomy, the type of soils and others. Areas with great inclination do not allow the rain water to accumulate while plain areas are more prone to flooding. Young plant species have not yet established deep rooting, thus are more vulnerable to injuries, inhibition of seed germination, changes in plant anatomy and mortality caused by the impetuous water flow. Maquis and garique vegetation, which consist 56% of the total forest and OWL area in Cyprus, are more sensitive to floods due to their lower height.

However, as it can be seen from Figure 8-12 and Figure 8-13, forest areas and OWL (including maquis and garique vegetation) are located in areas with inclination, thus they are not considered sensitive to flooding.

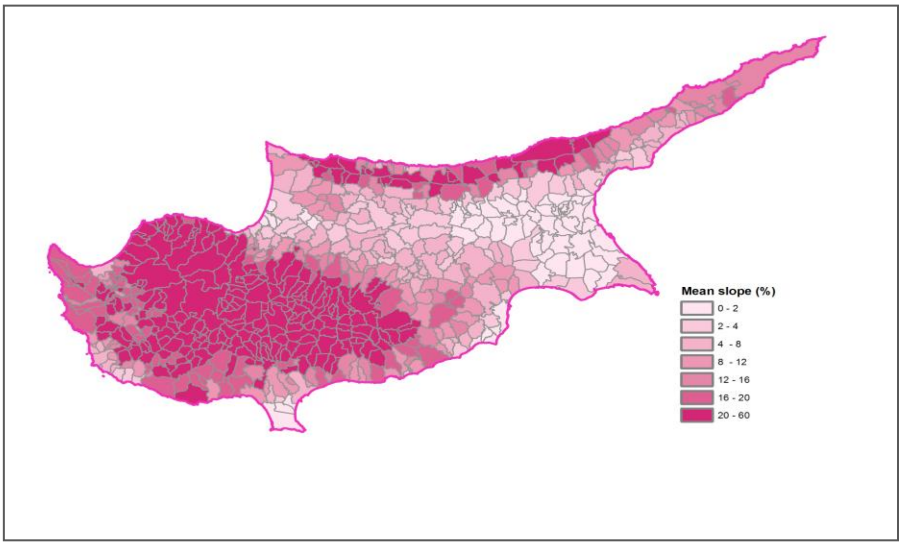


Figure 8-12: Island map depicting slope scores

Source: Deems, 2010

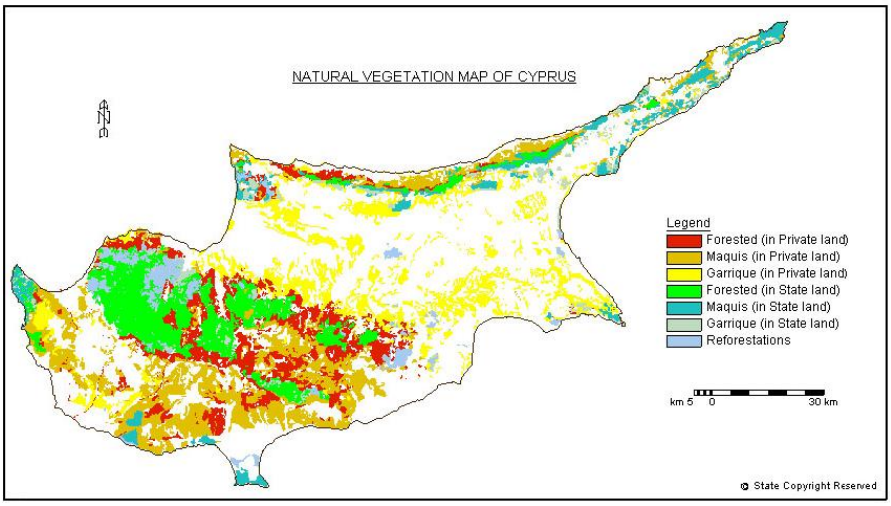


Figure 8-13: Natural vegetation of Cyprus

Source: Department of Forests, 2011a

Consequently, the sensitivity of Cyprus forests to floods is considered to be **limited.**

For the assessment of the sensitivity of Cyprus forests to wind throws and storm damages there were no relative data available.

Exposure

The Water Development Department of MANRE through its report "Preliminary Flood Risk Assessment" identified 19 areas around the island as "Areas with Potential Significant Flood Risk" (Figure 8-14). As it can be seen, the susceptible areas to floods are mainly the urban centers.

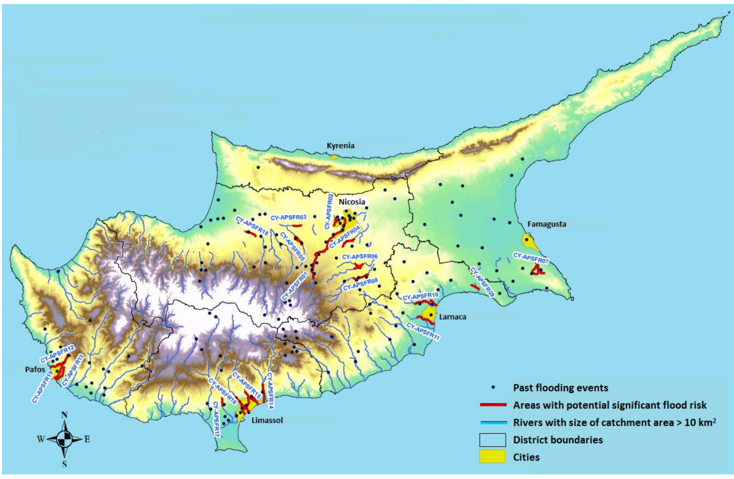


Figure 8-14: Areas with potential significant flood risk in Cyprus

Source: WDD, 2011

Thus, the exposure of Cyprus forests to floods can be characterized **limited**.

For the assessment of the exposure of Cyprus forests to wind throws and storm damages there were no relative data available.

8.4.3.2 Assessment of adaptive capacity

The Law 70(I) 2010 on the Flood Risk Assessment, Management and Preparedness, which harmonizes the Floods Directive 2007/60/EC with the Cypriot legislative framework states that Flood Hazard maps and Flood Risk maps must be prepared by the end of 2013, while Flood Risk Management Plans must be prepared by the end of 2015. The WDD has already implemented the preparatory steps in conformity with the EU Directive for the Preliminary Assessment of Flood Risks and has identified 19 areas in Cyprus as areas for which Potential Significant Flood Risks exist or might be considered likely to occur. Until 2015 the Flood Risk Management Plans for the identified areas is expected to be drawn in order for the necessary protective measures to be implemented.

However, the fact that there are limited flooding events in Cyprus forests without any human intervention for their protection, indicates that the forests themselves due to their topography (mountain areas) have the capacity to be self protected from floods (autonomous adaptive capacity), as water run-off finds its way to the plains. Therefore, the adaptive capacity of Cyprus can be characterized as **high.**

8.4.4 Forest growth

8.4.4.1 Assessment of sensitivity and exposure

Sensitivity

Due to the lack of sufficient information on the sensitive forest species of Cyprus to increased concentrations of air pollutants as well as to adverse climatic conditions such as increased temperature and decreased precipitation affecting their growth, the sensitivity of forest species in Cyprus was not assessed.

Exposure

The critical loads of acidity and nutrient nitrogen for Cyprus forest ecosystems were calculated in order to identify sites where deposition levels have reached a critical state and ecosystems could be at risk. Calculation of critical loads is based on a mass balance approach that takes into account atmospheric deposition, stand structure, bedrock and soil chemistry. Deposition scenarios compiled by the Centre for Integrated Assessment Modelling (CIAM) of the European Monitoring and Evaluation Programme (EMEP) were provided by the ICP Modelling and Mapping programme. A comparison between deposition rates and critical loads allowed to compute the so-called exceedance. For Cyprus at that time only the EMEP yearly deposition dataset of acidifying sulphur and nitrogen pollution (50 by 50 km grid cells, EMEP 2003) was available, allowing for a very rough estimation on exceedances. The comparison between the deposition values in 2000 with the critical loads showed that nowhere are exceedances in Cyprus (Nagel, 2003; LRTAP/IWF, 2011).

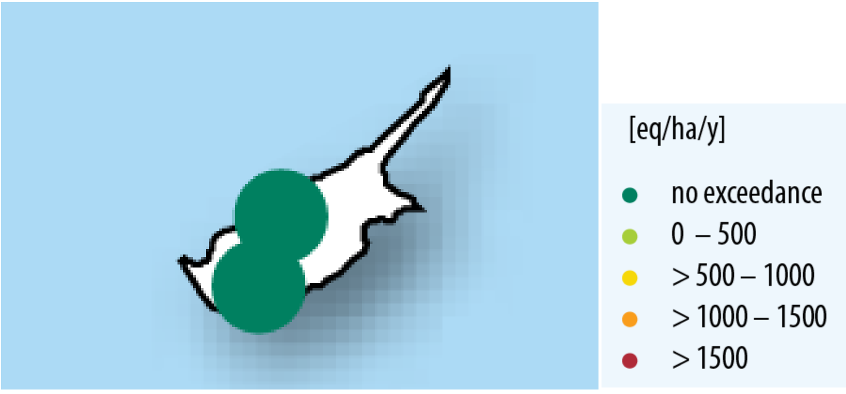


Figure 8-15: Exceedance of critical loads for nutrient nitrogen in 2000

Source: LRTAP/IWF, 2011

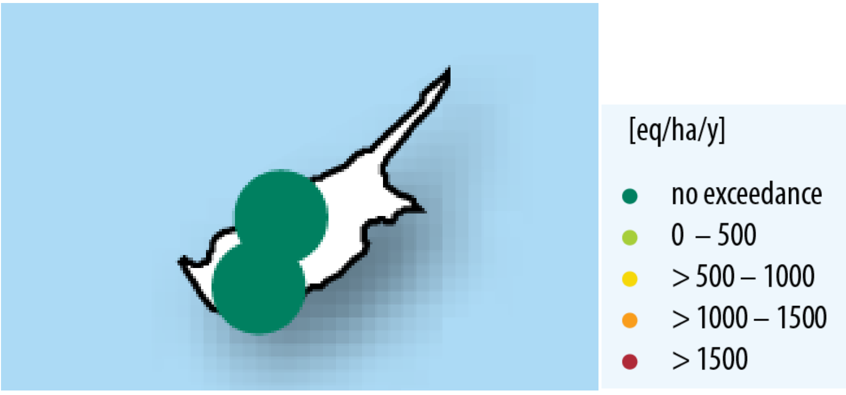


Figure 8-16: Exceedance of critical loads for acidity in 2000

Source: LRTAP/IWF, 2011

The reason is the relatively high acid neutralisation capacity of the mostly calcareous soils in Cyprus resulting in high critical loads. As depositions are actually underestimated, local sources were also taken into account. As a result it was estimated that about 17 % of the natural ecosystems area is stressed by acid depositions near the critical loads. The area is located at the lowlands between Pentadactylos and Troodos mountains. In these areas the main vegetation types are maquis and garique which are characterized by low critical loads. The comparison between the deposition values of nitrogen compounds in 2000 (EMEP 2003) with the critical loads shows exceedances in about 60 % of the Cyprian ecosystems. The critical loads of halophytic vegetation in salt lakes and lagoons near Ammochostos, Lemesos and Morfou are exceeded more than twice. But also at the Pentadactylos mountains the actual depositions are higher than critical loads. Also at the circum Troodos sedimentary succession area exceedance of critical loads is observed. Only critical loads at the Troodos forests are not exceeded at all (Nagel, 2003).

In addition, according to UNECE (2005), ozone is found at high concentrations in Cyprus forests and visible injuries have been detected on some forest species.

The areas most exposed to low precipitation, high temperatures and drought conditions especially during summer are the coastal areas (such as Paphos, Limassol, Larnaca and Famagusta) while the mountain areas (Troodos) are characterized by higher precipitation and lower temperature. However, it must be mentioned that the area of Troodos mountains where major state forests are located is featured by higher annual precipitation decreases for the period of 1917 to 2000 comparatively to the rest free part of Cyprus (Figure 8-6).

The areas most exposed to increases in mean temperatures when comparing the periods 2001-2008 and 1981-1990, are the western part of Cyprus between Paphos and Polis Chrysochous (up to 3.0-3.5 ^{o}C increase) and to a lesser extend the wider area of Larnaca and Famagusta (up to 1.5-2.0 ^{o}C increase). These areas are characterized mainly by maquis and garique vegetation (Figure 8-7).

The Standardized Precipitation Index, which provides a quantitative definition of drought, was computed for the case of Cyprus for the period 1970/71 - 2010/2011. The past 40 years have been marked by three extreme drought years, with an SPI below -2 (1972/73, 1990/91, 2007/08). There were also three years of moderate droughts (1989/90, 1999/00, 2005/06 and 12 years of mild drought (Cyprus Institute, 2011). From the SPI values it can be seen that drought events appear in Cyprus with great frequency while there are some years of quite intense droughts.

In absence of relative data on CO_2 concentrations, an overall assessment of the exposure did not take place.

8.4.4.2 Assessment of adaptive capacity

Cyprus has joined the International Co-operative Program on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP-Forests) in 2001 aiming at the better monitoring and understanding of ecosystems in Cyprus. The Cyprus Department of Forests of the Ministry of Agriculture, Natural Resources and Environment, has been nominated as the National Focal Centre of the ICP-Program in Cyprus, being responsible for the collection, validation, evaluation, storage and management of the monitoring data. In the context of this Program, 19 permanent plots have been established in Cyprus State forests aiming at the collection of the necessary data, relevant to the above activities. In monitoring plots, covering an area of 0.1 hectare each, the following ecosystems were monitored: Calabrian pine (Pinus brutia), Black pine (Pinus nigra), and Cyprus cedar (Cedrus brevifolia) ecosystems (Weiskel, 2009).

Monitoring of the effect of air pollution to Cyprus forests is the first step in the adaptation planning process. However, as soon as the effects of air pollution become fully understood the necessary actions must be undertaken in order to reduce to the degree possible adverse effects. From the European experience in the implementation of mitigation measures, it was seen that acidity has successfully abated, while increased concentrations of nutrient nitrogen in soils has not abated and it is expected to continue constitute a problem in the future based on current legislative framework. It must be noted that, even if no further increase in the pollution levels in soils was succeeded, it would take several decades for the rehabilitation of soils (LRTAP/IWF, 2011). Consequently, the adaptive capacity of Cyprus can be characterized as **limited to moderate**.

8.4.5 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of forests to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of forests against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

"Impacts" and "Adaptive capacity" should be evaluated on the same scale (1-7). For this to be achieved, the square root of "Sensitivity x Exposure" is used. The results of the vulnerability assessment for the forest sector in Cyprus are summarized in Table 8-15.

Table 8-15: Overall vulnerability assessment of forests in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Dieback of tree species, insect attacks and diseases	High to Very high (6)	High to Very high (6)	Limited to Moderate (2)	Moderate to High (4)
Fires	High to Very high (6)	High to Very high (6)	Moderate (3)	Moderate (3)
Floods	Limited (1)	Limited (1)	High (5)	None (-4)
Forest growth	Not evaluated	Not evaluated	Limited to Moderate (2)	-

As it can be seen from the table above, the first vulnerability priority for the forests of Cyprus is the impact of climate changes on the dieback of tree species, insect attacks and diseases as a significant part of Cyprus' forests has already been affected. The second priority regarding the vulnerability of forests to climate changes is related to the effect of increased frequency and intensity of forest fires as the latter cause severe and extended damages on forests. Finally, it was considered that the forests of Cyprus are not vulnerable at all to floods mainly due to the fact that they are located at mountains where the risk for floods is limited, while the vulnerability of forest growth to climate changes was not evaluated due to lack of sufficient data.

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9 FISHERIES & AQUACULTURE

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Abbreviations and Acronyms

DFMR	Department of Fisheries and Marine Research
CFP	Common Fisheries Policy
EU	European Union
FEAP	Fishing Effort Adjustment Plan
FMP	Fisheries Management Plan

9.1 Climate change and fisheries & aquaculture

The term 'fishery sector' includes sub sectors that are related with the following activities:

- Inshore and offshore fishery,
- Inland fishery,
- Marine and freshwater aquaculture.

Many people dependent on fisheries and aquaculture – as producers, consumers or intermediaries in inland or coastal areas – will be particularly vulnerable to the direct and indirect impacts of predicted climatic changes, whether through changes in physical environments, ecosystems or aquatic stocks, or through impacts on infrastructure, fishing or farming operations, or livelihood options (FAO, 2008). For the case of Cyprus, inland fishery is limited due to the lack of large water basins (lakes and/or rivers) and it is imply only sport fisheries mainly at dams. To this end, the study of climate change impacts and the respective adaptive measures will focus on inshore and offshore fishery and on marine and freshwater aquaculture.

9.2 Baseline Situation

9.2.1 Regulatory & managerial regime

The authority responsible for fishery matters in Cyprus is the Department of Fisheries and Marine Research (DFMR) of the Ministry of Agriculture, Natural Resources and Environment. The DFMR Head–Office is situated in Nicosia, and there are five District Units located in the four coastal towns of Limassol, Zygi, Larnaka, Pafos and Paralimni. There are also two research stations in operation at Meneou and Kalopanayotis, which are specialized in research and development of marine and freshwater aquaculture respectively. The activities of the DFMR concern the development and management of fisheries and aquaculture, marine ecology, the protection of endangered species and habitats, physical and chemical oceanography and the prevention and combat of marine pollution. Furthermore, the Department promotes supporting programs for the fishermen, including the construction of fishing shelters. It is also responsible for the enforcement of the relevant Legislation (Mitov A., 2009). Overall, the objectives and responsibilities of DFMR regarding fisheries are the following (Department of Fisheries and Marine Research, 2010):

- Formulation and implementation of policy for all segments of fishing fleet which includes:
  - small scale coastal fisheries,
  - polyvalent fisheries,
  - bottom trawlers operating in territorial and international waters and
  - recreational fisheries.
- Formulation and implementation of research projects towards the use of selective fishing gears and methods.
- Follow-up and reform of the current fisheries legislation.
- Coordination of the Council Regulation (EC) No 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea
- Follow-up of the reform of the Common Fisheries Policy (CFP) of the European Union (EU). The reform of the CFP takes place every 10 years. The respective process started in 2009; it will be intensified in 2011 and during the EU presidency by Cyprus it is expected that the new regulation of the CFP will be approved.

The current poor status of the most important fish stocks and the need to take immediate management measures has led the DFMR to prepare a Fisheries Management Plan (FMP) in 2010, entitled 'Fishing Effort Adjustment Plan (FEAP) of the Cyprus Fleet targeting demersal and mesopelagic stocks in the coastal zone of the Republic of Cyprus'. The FMP includes measures programmed by the Department of Fisheries and Marine Research (DFMR) of the Ministry of Agriculture, Natural Resources and Environment of the Republic of Cyprus, which are aimed at reducing the fishing effort for all categories of professional vessels that are active in the territorial waters, under the exclusive control of the Republic of Cyprus. The FMP has duration of three years and is the first intergraded FMP which has been prepared and came into force since Cyprus accession to the EU (Department of Fisheries and Marine Research, 2010).

The main measures, which have been programmed, include the permanent withdrawal of vessels, the use of more selective fishing methods, the reduction in the number of fishing licenses, the reduction in the permitted fishing tools, the creation of fishing protected areas and stricter control measures. The measures in question are collective measures, for which their combination will result in the recovery of the demersal and the mesopelagic species and improve, in the long-term, Cypriot fishermen's low income (Department of Fisheries and Marine Research, 2010).

The marine and fisheries policy aims at the protection and conservation of marine biodiversity and the conservation of fishstock. Among the most important tools for the conservation of marine biodiversity and the sustainable development of marine resources is the creation of marine protected areas. The marine protected areas have been designated in order to protect fragile ecosystems, endangered species and generally the marine biodiversity (Department of Environment Ministry of Agriculture, Natural Resources and Environment, 2010).

Generally the laws and regulations, mainly intent to regulate matters concerning the fishing sectors, to verify fishing intensity and aim to control marine pollution and the protection of marine habitats and species (Department of Environment Ministry of Agriculture, Natural Resources and Environment, 2010).

9.2.2 Sectors

All the activities that are related with fishery are divided in the following sectors:

- Inshore & Pelagic Fishery,
- Marine Aquaculture,
- Inland Fishery and
- Freshwater Aquaculture.

9.2.2.1 Inshore & pelagic fishery

According to the Cyprus Fisheries Law, the Cyprus fishing fleet regarding inshore and pelagic fishery is categorized into three fleet segments, namely, the small scale inshore boats, the polyvalent vessels and the bottom trawlers (Department of Fisheries & Marine Research, 2007).

The small scale inshore boats, with an overall length between 6 – 12m, operate using passive polyvalent gears and mainly bottom set nets. Until 2006 Cyprus Fisheries Law provided that a maximum number of 500 licenses are provided for this segment annually. A number of restriction measures on the use of fishing gears and minimum landing sizes are enforced, according to the national and community law (Cyprus's National Fisheries Data Collection Programme, 2007).

The polyvalent vessels have an overall length between 12 – 24 m and operate using passive polyvalent gears. The term 'polyvalent vessels' is used because these vessels are engaged in two types of fisheries; mainly in the large pelagic fishery using drifting longlines and operating around Cyprus waters and the eastern Mediterranean (targeting swordfish, bluefin tuna and albacore), and also in the inshore demersal fishery using mostly bottom set nets and bottom longlines. The fleet is comprised of about 30 licensed vessels (Department of Fisheries & Marine Research, 2007).

The bottom trawlers have an overall length between 21-27 m and are categorized, according to their type of license, in those fishing in the territorial waters of Cyprus and those fishing in international waters (eastern and central Mediterranean). Since 2011 the licensed vessels fishing in territorial waters are limited to 2, while the fleet operating in international waters is comprised of about 6 trawlers (Department of Fisheries & Marine Research, 2007).

In 1988 capture fisheries represented in quantity about 98% of the total domestic fisheries (capture fisheries and aquaculture), while in 1998 its contribution dropped to 67.2% (70.3%), because of the dramatic increase of marine aquaculture production. As regards value of production, capture fisheries in 1998 represented about 64% (66%) of the total domestic fisheries. All fish are landed in fresh form. The main source of supply of Cyprus capture fisheries is the inshore fishery which represented in 1998 about 42% (46%) of the total domestic fisheries catch, while trawl fishery in Cyprus and in international waters comprised about the 13% and 10% (14% and 8%) respectively (Stephanou D., 2003).

Inshore fishery management also includes the development of fishing shelters. In particular, fishing shelters are constructed for the protection of small fishing boats against extreme events such as storms and large waves. Inshore fishery management is a responsibility of the Department of Fishery and Marine Resources (DFMR). In this framework, the construction works for the new fishing shelter at Zygi started in December 2007 and were completed in 2011. The fishing shelter will have the capacity of 220 vessels, and will also assist in the socioeconomic development of the area. In July 2010, it has been officially declared as fishing shelter by the Minister of Agriculture, Natural Resources and Environment. Improvement works are being carried out at the fishing shelters of Kato Pyrgos, Pomos, Dhekelia and Larnaca (Department of Fisheries and Marine Research, 2010).

Fishery of swordfish was, until recently, the only organized pelagic fishery on the island. In 1999 the first commercial purse seining unit for the fishing of small pelagic fish mostly by light fishing (attraction by lights) started to operate on an experimental basis. The economic viability of this pelagic fishery in Cyprus has to be proved, due to the unknown size of the stocks and the low price that most of its catch fetches in the local market, with the exception of bogue. Swordfish fishery production is fluctuating between 100-200 t/year (Stephanou D., 2003).

As for the pelagic fishery fauna, other pelagic fish, like the amberjack, are caught by fishermen and sport fishermen in small quantities by trolling and spear gunning. Trolling off the coast of Cyprus for pelagic fish, mostly albacore has become a popular sport in the last 2-3 years. The catch which originates from sport fishing is not allowed to be sold (Stephanou D., 2003).

9.2.2.2 Marine aquaculture

In 2010, there were in operation three marine fish hatcheries and one inland shrimp hatchery/farm, seven private offshore cage farms culturing mainly sea bass and sea bream and two offshore cage farms culturing / fattening blue fin tuna. Additionally, there were in operation eight small trout farms, culturing mainly rainbow trout and two farms culturing ornamental fish (Department of Fisheries and Marine Research, 2010).

The fattening units for marine fish production operate on an intensive basis, using the method of offshore cages. The cages are located at a distance of 1 to 4 km from the shore, at water depths ranging from 18 - 70 meters and with a distance of about 2 km between each other. The main reasons for adopting this culture method are the high competition for the use of the coastal land and sea area and more importantly the fact that this system is considered as having the least impact on the environment and provides the best possible condition for the fish in terms of animal welfare (http://www.moa.gov.cy/moa/dfmr/dfmr.nsf).

The total licensed production capacity of Cyprus aquaculture for 2010 was 7,120 tons of table size fish, 22,520,000 fingerlings / fry and 1,020,000 fish for the ornamental fish trade.

The estimated production and value of Cyprus aquaculture for 2010 is shown in the tables below (Department of Fisheries and Marine Research, 2010).

Table 9-1: Estimated production & value of Cyprus aquaculture, grow - out units (table size products) (2010)

Species	Local Market		Exports		Total	
	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)
Seabream	1,068	5,264,000	1,705	8,012,000	2,773	13,277,000
Seabass	650	3,291,000	555	2,824,000	1,205	6,115,000
Japanese Seabream	14	83,000	0	0	22	85,000
Rabbit Fish	5	41,000	0	0	5	41,000

Species	Local Market		Exports		Total	
	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)
Meagre	2.8	27,000	0	0	2.8	27,000
Rainbow Trout	65	530,000	0	0	65	530,000
Sturgeon	4.5	54,000	0	0	4.5	54,000
Tilapia	0.1	1,500	0	0	0.1	1,500
Total	**1809.4**	**9,291,500**	**2,260**	**10,836,000**	**4,077.4**	**20,130,500**

Table 9-2: Estimated production & value of Cyprus aquaculture, hatcheries (fry – fingerlings) (2010)

Species	Local Market		Exports		Total	
	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)	Quantity (tons)	Value (€)
Seabream	9,101,000	1,483,000	0	0	9,101,000	1,483,000
Seabass	2,695,000	420,000	0	0	2,695,000	420,000
Japanese Seabream	7,500	1,200	0	0	7,500	1,200
Trout	370,000	11,000	0	0	370,000	11,000
Ornamental	30,000	32,000	29,000	46,000	59,000	78,000
Total	**12,203,500**	**1,947,200**	**29,000**	**46,000**	**12,232,500**	**1,993,200**

In 2010 the total value of aquaculture products (table size and fry) reached € 22.1 million out of which € 10.9 million were generated from exports.

The majority of the production of fry was marketed locally to Cypriot grow – out units except from a small quantity of ornamental fish, as it is shown on the table above.

Trout production in 2010 remained on the same level as 2009 due to the serious and long draught period. The Seabass / Seabream production though, was significantly higher than the previous year. The worldwide price crisis that began during the second half of 2008 and affected also the production and value of aquaculture in 2009, showed some signs of recovery during 2010. As in 2009, in 2010 there was no production of Blue Fin Tuna (Department of Fisheries and Marine Research, 2010).

The DFMR is operating two research stations, the Meneou Marine Aquaculture Research Station (MeMARS) and the Fresh Water Aquaculture Research Station at Kalopanayiotis. Both stations have been modernized during 2010 with the most important project being the construction of new facilities for the MeMARS (Department of Fisheries and Marine Research, 2010).

9.2.2.3 Inland Fishery

In 2010 the DFMR issued 2630 individual and 16 group recreational angling permits for recreational fishing in dams and reservoirs. Within the framework for the promotion and development of recreational angling, 30.000 trout and a small number of other fish were released in several dams and reservoirs (Department of Fisheries and Marine Research, 2010).

9.2.2.4 Freshwater aquaculture

In Cyprus, there are in operation seven small freshwater farms, located in the Troodos mountain range. The only freshwater species cultured on a commercial basis for human consumption is the rainbow trout (Oncorhynchus mykiss). Additionally there are two small farms for the culture of ornamental freshwater fish, like Koi-carps (Cyprinus carpio) and varieties of gold fish (Carassius sp.). In 2008 the commercial culture of Siberian sturgeon (Acipenser baerii) has began on an experimental basis.

Trout is produced on land based intensive systems (raceways) and seasonally, in cages located in the irrigation reservoirs (dams).

Trout farms employ a small number of individuals with empirical technical knowledge, usually operating small family businesses. Two out of the six trout farms, operate in conjunction with adjacent restaurants. Trout farming creates employment opportunities in the mountainous areas and contributes to the creation of activity and the encouragement of residents to stay in these isolated rural regions.

9.3 Impact assessment

Climate changes are affecting fisheries and aquaculture directly by influencing fish stocks and the local supply of fish for consumption, or indirectly by influencing fish prices or the cost of goods and services required by fishers and fish farmers (World Fish Centre, 2007). These changes are related with certain impacts such as sea level rise, alteration of inland and sea water temperature etc.

The magnitude of climate change impacts is depending on the vulnerability of each community, the combination of potential impacts (sensitivity and exposure) and adaptive capacity. Impacts would be felt through changes in capture, production and marketing costs, changes in sales prices, and possible increases in risks of damage or loss of infrastructure etc.. Fishery-dependent communities may face increased vulnerability in terms of less stable livelihoods, decreases in availability or quality of fish for food, and safety risks due to fishing in harsher weather conditions and further from their landing sites (Food & Agriculture Organization of the United Nations, 2008).

Impacts on aquaculture are arising from direct and indirect impacts on the natural resources namely water, land, seed, feed and energy. As fisheries provide significant feed and seed inputs, the impacts of climate change on them will affect the productivity and profitability of aquaculture systems (Food & Agriculture Organization of the United Nations, 2008).

Climatic changes could increase physiological stress on cultured stock. This would not only affect productivity but also increase vulnerability to diseases. Interactions of fisheries and aquaculture subsectors could induce other impacts also. For example, extreme weather events could result in escapes of farmed stock and contribute to reductions in genetic diversity of the wild stock, affecting biodiversity more widely (Food & Agriculture Organization of the United Nations, 2008).

In fisheries, while climate change has been addressed occasionally in scientific literature, the subject has not yet been formally addressed by most industry or fishery management administrations. However, the fishery sector and fisheries research are fairly advanced in this matter, through their dealing with the El Niño, decadal changes in ocean environments and other longer terms fluctuations in fisheries environments and resources. The observation programs, scientific analyses, computer models, the experience gained and strategies developed by fishers, processors, fishfarmers, and management authorities confronted with the problem of medium-to-long-term natural fluctuations, is extremely useful for dealing with climate change. Many of the principles and strategies developed to deal with ‘unstable’ stocks will be of use when having to deal with climate change (http://www.fao.org/fishery/).

In particular, climate change factors which affect the fisheries sector (inshore, pelagic, offshore fishery and aquaculture) include:

- Sea Water and inland temperature changes,
- Sea Level Rise (*SLR*),

- Precipitation,
- Extreme events.

These impacts are correlated with the most notable climatic changes in the following table.

Table 9-3: Relationship between observed climate changes and impacts on the fisheries sector

Climate changes	Impacts on fishery sector
Sea water and inland temperature changes	– Alterations in abundance and species composition of fish stocks – Potential loss of species or shift in composition in capture fisheries – Changes in infrastructure and operating costs from worsened infestations of fouling organisms, pests, nuisance species and/or predators – Potential for increased production and profit, – Alterations on seed availability – Reductions in fish stocks – Possibly enhanced fish stocks or else reduced growth where the food supply does not increase sufficiently in line with temperature – Possible benefits for aquaculture, especially intensive and semi-intensive pond systems – Possibly higher capital costs for aeration equipment or deeper ponds
Sea Level Rise	– Reduced area available for aquaculture – Loss of freshwater fisheries – Shifts in species abundance, distribution and composition of fish stocks and aquaculture seed – Damage to freshwater capture fisheries – Reduced freshwater availability for aquaculture and a shift to brackish water species – Reduced recruitment and stocks for capture fisheries and seed for aquaculture – Worsened exposure to waves and storm surges and risk that inland aquaculture and fisheries become inundated
Changes in precipitation and water availability	– Higher costs of maintaining pond water levels and from stock loss – Reduced production capacity – Conflict with other water users – Change of culture species – Altered distribution, composition and abundance of fish stocks – Fishers forced to migrate more and expend more effort
Increase in the frequency and intensity of extreme	– Loss of aquaculture stock and damage to or loss of aquaculture facilities and fishing gear

Climate changes	Impacts on fishery sector
weather events	– Impacts on wild fish recruitment and stocks – Higher direct risk to fishers; capital costs needed to design cage moorings, pond walls, jetties, etc. that can withstand storms and insurance costs – Loss of wild and cultured stock. Increased production costs – Loss of opportunity as production is limited – Reduced wild fish stocks, intensified competition for fishing areas and more migration by fisherfolk

The aforementioned impacts are presented next in detail under the following categories:

- Quantity and diversity of fishstocks
- Fishstock physical environment
- Cost implications for fishermen

9.3.1 Quantity and diversity of fishstocks

The main climatic factors that are responsible for the alterations on the quantity and diversity of fishstocks are: (a) the changes in sea water temperature, for the inshore, offshore and pelagic fishery and (b) the changes in inland temperature for the aquaculture.

Analyses of annual mean satellite Sea Surface Temperature (SST) data indicate that over the last 16 years (1996-2011) a general warming has occurred over the Levantine Basin where Cyprus belongs, and occurred at an average rate of approximately 0.065°C per year (Samuel-Rhoads Y. et al.). This rate is more than three times higher than the recorded 0.18°C/decade rate of increase of global SSTs (Good S.A. et al., 2007). Further, satellite SST data are correlated with in-situ CTD SST data, especially during the summer months. The warming in the Levantine, which is revealed by the satellite SST data, as well as by the recorded increases of in-situ SST, occurred at both seasonal and interannual time scales.

(a) Inshore, offshore and pelagic fishery

In general, the climate change induced impacts (mainly related with increased seawater temperature) on the quantity and diversity of fishstocks, are the following (World Fish Centre, 2007):

- More frequent harmful algal blooms,
- Less dissolved oxygen in sea waters,
- Increased incidences of diseases and parasites,
- Altered local ecosystems with changes in competitors, predators and invasive species,
- Changes in plankton composition,

- Longer growing seasons,
- Lower natural mortality in winter,
- Enhanced metabolic and growth rates,
- Enhanced primary productivity,
- Changes in timing and success of migrations, spawning and peak abundance, as well as in sex ratios,
- Changes in the location and size of suitable range for particular species,
- Changed location and timing of sea currents and upwelling alters nutrient supply in surface waters and, consequently, primary productivity.

The aforementioned alterations on the quantity and diversity of fishstock induce subsequent impacts on the fishery sector (inshore, offshore and pelagic fishery). These impacts include (World Fish Centre, 2007):

- Alterations in abundance and species composition of fish stocks,
- Potential loss of species or shift in composition in capture fisheries,
- Potential species loss and altered species composition for capture fisheries,
- Changes in abundance of juvenile fish and therefore production in marine water (reduced fish recruitement). This impact is mainly related with changes in seawater currents.
- Changes in fish migration and recruitment patterns and so in recruitment success

(b) Aquaculture

In general, regarding the alterations on the quantity and diversity of fishstocks due to changes in inland temperature, these include (World Fish Centre, 2007):

- Increased stratification and reduced mixing of water in lakes, reducing primary productivity and ultimately food supplies for fish species,
- Raised metabolic rates increase feeding rates and growth if water quality, dissolved oxygen levels, and food supply are adequate, otherwise possibly reducing feeding and growth,
- Potential for enhanced primary productivity,
- Shift in the location and size of the potential range for a given species,
- Reduced water quality, especially in terms of dissolved oxygen
- Changes in timing and success of migrations, spawning and peak abundance,
- Changes in the range and abundance of pathogens, predators and competitors;
- Invasive species introduced.

In particular, regarding the invasive species, biological invasions represent a significant risk for many natural ecosystems and have become an issue of increasing concern worldwide. The Mediterranean Sea is one of the regions most severely affected by alien marine invasions, fostered by the opening of the Suez Canal, fouling and ballast transportation along shipping lines, aquaculture, and the aquarium trade. The overall estimation of marine alien species in the Mediterranean Sea represents approximately 7.5% of the known flora and fauna. However, this percentage is higher in the Eastern Mediterranean and may exceed 20% in specific aquatic ecosystems. The Eastern Mediterranean is highly susceptible to marine biological invasions because of its location at the crossroads between the Ponto-Caspian and the Indian Ocean/Red Sea regions, the maritime traffic from the Indian Ocean, and a widespread occurrence of fish and shellfish farms. Lessepsian immigrants in particular are mostly confined to the eastern part of the Mediterranean basin and especially in sea waters around Cyprus (Mitov, 2009).

The aforementioned alterations on the quantity and diversity of fishstock induce subsequent impacts on the fisheries sector (aquaculture). These impacts include (World Fish Centre, 2007):

- Changes in infrastructure and operating costs from worsened infestations of fouling organisms, pests, nuisance species and/or predators[27],
- Changes in abundance of juvenile fish and therefore production in fresh water (reduced fish recruitement). This impact is mainly related with changes in fresh water currents (mainly for rivers).
- Possible benefits for aquaculture, especially intensive and semi-intensive pond systems (potential for increased production and profit),
- Alterations on seed availability.

<u>Situation in Cyprus</u>

Regarding the temperature changes at the inland of Cyprus, long term temperature records from Cyprus were collected and analyzed to investigate the long-term changes in the diurnal temperature cycle. Only two of the stations (Limassol and Nicosia) had long enough records, with no major relocation problems, for this analysis (Price C. et al., 1999).

At both stations similar annual mean temperature changes are observed. A warming of approximately 1–1.5 Celsius degrees has occurred over the last 100 years, approximately twice the global increase observed in the same period. Although the annual mean temperature at both locations increases at a similar rate, the minimum and maximum annual mean temperatures are differentiated. At Limassol, a coastal station on the south shore of Cyprus, all of the warming has resulted from the increase in the minimum

[27] Higher capital costs are associated with additional cost burden for aeration equipment or deeper ponds and higher operating costs are associated with altered culture species and possibly worsened losses to disease

temperature. In fact, there has been a decrease in the maximum temperature during this century. At Nicosia, an inland station in the northern part of Cyprus, the maximum and minimum temperatures have both increased during the century, although the minimum temperatures have increased at a faster rate. Therefore, both locations show significant decreases in the annual mean diurnal temperature range (Price C. et al., 1999).Moreover, as for the introduced invasive species, the Department of Fisheries and Marine Research (DFMR) in collaboration with the Hellenic Centre for Marine Research published a scientific report on marine invasive species in Cyprus which includes an inventory of 126 alien marine species reported in the country's territory (Katsanevakis et al, 2009).

9.3.2 Fishstock physical environment

Alterations on fishstock physical environment regarding marine and freshwater fishery and aquaculture are attributed mainly to extreme events in general and for ecosystems that are located nearby the coastal zone to storm surges and sea level rise in particular. The water quality of inland aquaculture and fisheries is affected by changes in precipitation and temperature.

(a) Sea Level Rise/ storm surges

In general, global average sea level is rising mainly because of (Shoukri E., Zachariadis T., 2012):

- Thermal expansion of warming ocean water,
- Addition of new water from: ice sheets of Greenland and Antarctica, from glaciers and ice caps,
- Addition of water from land surface runoff.

There is strong evidence that global sea level gradually rose in the 20th century and is currently rising at an increased rate and is projected to rise during the 21st century at even greater rate. Estimates for the 20th century show that global average sea level rose at a rate of about 1.7mm per year. The average rate of sea level rise from 1961 to 2003 was 1.8mm/year and increased to 3.1mm/year from 1993 to 2003. Climate model projections, satellite data and hydrographic observations show that sea level is not rising uniformly around the globe. In some regions, rates are up to several times the global mean rise, while in other regions sea level is falling (Shoukri E., Zachariadis T., 2012).

For the Mediterranean basin, satellite measurements calculate that sea level has been rising at a rate of 2.4 to 3.8 mm/yr since 1993, more than 50% faster than the rate that tide gauges estimate over the last century. Therefore, sea level appears to be rising about 50% faster than recent models suggest. Although there is no proof for their lack of validity, given the uncertainty of the models, satellite measurements suggest that average sea level rise rate is being underestimated (Ramos-Esplá et al., 2007).

In general, regarding the climatic change impacts on fishery sector due to sea level rise and increased intensity and frequency of storm surges, these are referring to alterations on the physical environment of marine and freshwater fishstocks. These alterations include (World Fish Centre, 2007) & (Nicholls et al., 2007):

- Loss of land,
- Changes to estuary systems,
- Salt water intrusion into groundwater,
- Loss of coastal ecosystems and/or loss of coastal habitats.

The aforementioned alterations imply also the following impacts for the fishery sector (World Fish Centre, 2007):

- Reduced area available for aquaculture,
- Loss of freshwater fisheries,
- Shifts in species abundance, distribution and composition of fish stocks and aquaculture seed,
- Damage to freshwater capture fisheries,
- Reduced freshwater availability for aquaculture and a shift to brackish water species,
- Reduced recruitment and stocks for capture fisheries and seed for aquaculture,
- Worsened exposure to waves and storm surges and risk that inland aquaculture and fisheries become inundated.

(b) Decreased precipitation and increased temperature

Increasing seasonal and annual variability in precipitation and subsequent flood and drought extremes are likely to be the most significant drivers of change in inland aquaculture and fisheries.

In general, regarding the climatic change impacts on fishery sector due to changes in precipitation and water availability, these are referring mainly to alterations on water quality. These alterations include (World Fish Centre, 2007):

- Lower water availability for aquaculture,
- Lower water quality (e.g algal blooms) causing more diseases,
- Increased competition with other water users,
- Altered and reduced freshwater supplies with greater risk of drought,
- Higher costs of maintaining pond water levels and from stock loss,
- Changes in lake and river levels and the overall extent and movement pattern of surface water.

Situation in Cyprus

Sea Level Rise: Based on archaeological data, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm per year. This uplift will counteract global sea-level rise and given a global rise in sea level of 0.5m by 2100, relative sea-level rise in Cyprus will be in the range 0.4-0.5m. This is a significant change which needs to be taken into account when planning sustainable solutions for coastal zone problems (Nicholls and Hoozemans, 1996).

Changes in precipitation: The rate of decrease of the average precipitation in Cyprus during the 20th century and at the beginning of the 21st was one millimeter per year. The decrease in precipitation occurred mainly in the second half of the century, as a result of the higher frequency of occurrence in the number of years of low precipitation and drought (http://www.moa.gov.cy/moa/dfmr/dfmr.nsf/).

Similar conclusion in drawn from the examination of the average precipitation in various 30-year periods: 1901-1930: 559 mm, 1931-1960: 524 mm, 1961-1990: 503 mm, 1971-2000: 462 mm. The average precipitation in the last 30-year period is 17% less than in the period 1901-1930. The average precipitation in the last decade of the century is among the lowest values for the various decades of the century (http://www.moa.gov.cy/moa/dfmr/dfmr.nsf/).

9.3.3 Cost implications for fishermen

The main cost implications of climate induced impacts for fishermen are mainly attributed to extreme weather events and include the following (World Fish Centre, 2007):

- Loss of harbours and coastal infrastructure (e.g households) (mainly attributable to sea level rise),
- Decreased frequency of offshore, inshore and pelagic fishing/ Fewer days at sea (mainly attributable to increased intensity and frequency of storms),
- Higher direct risk to fishers; capital costs needed to design cage moorings, pond walls, jetties, etc. that can withstand storms and insurance costs,
- Loss of aquaculture stock and damage to or loss of aquaculture facilities and fishing gear. Aquaculture installations (coastal ponds, sea cages) at greater risk of damage (mainly attributable to increased intensity and frequency of storms),
- Loss of wild and cultured stock. Increased production costs and loss of opportunity as production is limited,

9.4 Vulnerability assessment

In this section, the vulnerability of the fishery sector is assessed in terms of its sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which the fishery sector is affected by climate changes, exposure is the degree to which the fishery sector is exposed to climate changes and its impacts while the adaptive capacity is defined by the ability of the fishery sector to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The indicators used for the assessment of sensitivity, exposure and adaptive capacity of the Cypriot fisheries sector to climate change impacts are summarized in Table 9-4.

Table 9-4: Indicators used for the vulnerability assessment of climate change impacts on the fisheries sector Cyprus

Vulnerability Variable	Selected Indicators
Quantity and Diversity of Fishstocks	
Sensitivity	– Rates of production of coastal marine and freshwater systems – Mean changes in timing and levels of productivity across marine and freshwater systems – Rates of production of target species in marine and freshwater systems – Changes in infrastructure and operating costs from worsened infestations of fouling organisms, pests, nuisance species and/or predators
Exposure	– Changes in the productivity of fished species – Declines in production due to mismatch between prey (plankton) and predator (fished species)
Adaptive capacity	– Economic incentives (Operational Programme for Fisheries 2007-2013) – Grants – Research programmes
Fishstock Physical Environment	
Sensitivity	– Annual deviations in number of freshwater aquaculture fisheries – Annual deviations shifting number in species abundance – Changes in production of inshore, offshore and pelagic fisheries

Vulnerability Variable	Selected Indicators
	systems
Exposure	– Surface area available for aquaculture – Volume of freshwater availability for aquaculture
Adaptive capacity	– Construction of Coastal Defense Works – Development of fishing shelters – Designation of marine protected areas – Artificial reefs – Measures for the protection of water quality
Cost implications for fishermen	
Sensitivity	– Deviations in production cost of inshore, offshore and pelagic fishery due to extreme events – Cost of damages from storm surges on aquaculture – Cost of maintaining pond water levels and from stock loss – Cost of damages to freshwater capture fisheries
Exposure	– Frequency of storm surges – Number of fishers migration
Adaptive capacity	– Economic incentives are provided by the Operational Programme for Fisheries 2007-2013

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

To assess the vulnerability of the fishery sector, the following impacts were considered:

1. Quantity and diversity of fishstocks,
2. Fishstock physical environment,
3. Cost implications for fishermen.

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability. In case additional data are provided by the competent authorities of Cyprus, the vulnerability of the sector could be re-assessed.

9.4.1 Quantity and diversity of fishstocks

9.4.1.1 Assessment of sensitivity and exposure

Sensitivity

Sea waters of the Levantine basin are sensitive to temperature changes leading to alterations on the quantity and diversity of fishstock and therefore, affecting inshore, pelagic and offshore fishery mainly as for the rates of productivity. Deviation in inland temperature affects mainly aquaculture and freshwater fishery and the respective fishstocks.

Since the temperature of sea waters is expected to be increased in the future, Cyprus' fishery sector will be affected due to the alteration of the quantitative and metabolic characteristics of a great variety of fishes leading to deviation in number of species subjected to fishing. Furthermore, the alterations of inland temperature will affect aquaculture and freshwater fishstock populations.

Regarding the fishery sector of Cyprus, the indicators that can measure the sensitivity of fishery sector against alterations on the quantity and diversity of fishstocks, regarding inshore, offshore and pelagic fishery are including (Allison et al., 2009):

- 'Rates of production of coastal marine and freshwater systems',
- 'Mean changes in timing and levels of productivity across marine and freshwater systems',

- 'Rates of production of target species in marine and freshwater systems' and
- 'Changes in infrastructure and operating costs from worsened infestations of fouling organisms, pests, nuisance species and/or predators'.

For the case of Cyprus, there are no available data regarding the correlation among changes of sea water and inland temperature and alterations on the quantity and diversity of fishstocks, regarding the sensitivity of fishery sector. Thus no characterization was given to the sensitivity of quantity and diversity of fishstocks due to climate change.

Exposure

Due to its geographical position at the Levantine basin, Cyprus is exposed to the increase temperature due to climatic changes. Furthermore, the proportional increase regarding sea waters and inland temperature is expected to affect aquaculture, offshore, inshrore and pelagic fishstocks and therefore, the entire fishery sector leading to economical effects due to deviation in the amounts of fishes.

The indicators that can measure the consequences of temperature changes regarding the exposure of fishery sector of Cyprus are expressed as following:

- 'Changes in the productivity of fished species' and
- 'Declines in production due to mismatch between prey (plankton) and predator (fished species)'.

Furthermore, due to its geographical position, Cyprus sea waters are exposed to the invasion of alien species. The indicator that is expressed as 'marine alien species in the Eastern Mediterranean as a percentage of total fishstock's fauna' (20%) shows that pelagic and offshore fishery of Cyprus is subjected to alterations of fishstock's fauna.

For the case of Cyprus, there are no available data regarding the correlation among changes of sea water and inland temperature and alterations on the quantity and diversity of fishstocks, regarding the exposure of fishery sector. Thus no characterization was given to the exposure of quantity and diversity of fishstocks due to climate change.

9.4.1.2 Assessment of adaptive capacity

The measures that can be undertaken against alterations on the quantity and diversity of fishstocks due to sea water and inland temperature changes are referring to the following activities (Food & Agriculture Organization of the United Nations, 2008):

- For aquaculture, the usage of better feeds, more care in handling, selective breeding and genetic improvements for higher temperature tolerance (and other related conditions).
- Increasing feeding input in order to adjust harvest and market schedules,

- Improving planning to conform to predictions by establishing regular monitoring and emergency procedures.
- Focus management to reduce stress by setting up biosecurity measures, by monitoring to reduce health risks by improving treatments and by making genetic improvements for higher resistance.
- Identification of fish meal and fish oil replacement, developing new forms of feed management, making genetic improvement for alternative feeds, shifting to non-carnivorous species.
- Modernisation and upgrading of existing fishing technology (provided there in no increase in the ability to catch fish). The use of appropriate fishing equipment and of environmentally friendly methods may contribute to more effective control of fishing activities and thus enhancing preparedness under climate changes.
- Modernisation of existing aquaculture units. Modernisation may improve the environmental impact on the marine environment and at the same time increase the productive capacity, thus enhancing adaptive capacity.
- Diversification of production. The diversification of aquaculture production may reduce risk due to reduced productivity of certain less climate resilient fishes by compensating with the increased productivity of some other fishes that may benefit from climate changes.

For the case of Cyprus in particular, the following measures have been undertaken:

Economic incentives (Operational Programme for Fisheries 2007-2013):

- **Socio-economic compensation for the management of the fishing fleet (1. Scheme for providing support to young fishermen for acquiring ownership of a fishing vessel, 2. Early retirement scheme for fishermen)**. This measure contributes to the financing of socio-economic actions such as support for young fishermen to acquire for the first time part or total ownership of a fishing vessel, a chance for them to upgrade their skills and receive professional training, the chance for their activities´ diversification and finally early retirement from the fishing sector. For the early retirement measure, the beneficiaries are fishermen between the age of 55 to 65 who meet certain criteria.
- **Funding scheme for investments in the marketing and processing of fisheries products.** This measure aims to the development of the processing and marketing of fishery and aquaculture products sector. The funds are given in order to encourage and promote investments in this sector, to improve the quality of the products, to produce high quality fishery and aquaculture products, to adapt and apply new technologies, to preserve and increase the number of job positions and reduce the negative impacts on the environment.

Grants:

Furthermore, the Department of Fisheries and Marine Research, taking into account the reports from fishermen regarding the substantial increase and spread of the population of the IAS of Lagocephalus and the damage caused to the fishing gear and catches, prepared a study on the species in the coastal waters of Cyprus. After evaluating the results of the study, the DMFR developed a management plan entitled ‘Plan for the control of the population of Lagocephalus sceleratus in the coastal waters of Cyprus’ and in 2012 announced the call for proposals for the implementation of the plan in the framework of the ‘Project Grants for collective actions in the Fisheries Sector’. The purpose of the call is to eliminate the populations of lagocephalus from the coastal commercial fleet of Cyprus, with the exercise of intense fishing pressure on breeding population of the species, just before and during the breeding season, in the main breeding areas of the species.

Research programmes

Regarding the diversification of production, the research programmes that have been undertaken at the Meneou Marine Aquaculture Research Station (MeMARS) focused mainly on new candidate species for fish farming, such as rabbit fish (Siganus rivulatus), common pandora (Pagellus erythrinus), common dentex (Dentex dentex), greater amberjack (Seriola dumerili) and meagre (Argyrosomus regius). The main objective of the research was the diversification of aquaculture production with new species. The main projects during 2010 were:

- Reproduction and larval rearing protocols for the mass production of fry of the rabbitfish (Siganus rivulatus) and fattening in sea cages of market size fish,
- The effect of illumination in the ability of capturing live feed in rabbitfish larvae,
- Study of the effect of temperature and oxygen concentration on the metabolism of rabbitfish,
- Evaluation of vitamin C and astaxanthin supplementation in broodstock diet on reproductive performance and egg and larval quality in common pandora (Pagellus erythrinus),
- Evaluation of different feeds for the fattening of greater amberjack and observation of its feeding behaviour,
- Management of amberjack broodstock, performing a trial on reproduction using LHRHa hormone implants,
- Fattening of meagre in tanks and observation of its feeding behaviour, and
- Evaluation of the culture of rotifers with different feeds and determination of their nutritional value.

Moreover, the MeMARS is participating in a) the European Thematic Educational Network AQUA-TNET, which is funded from the European Commission Socrates Erasmus Programme,

b) the European Network Programme COST Action 867 “Welfare of fish in European aquaculture”, c) the European Network Programme COST Action FA0801 “Critical success factors for fish larval production in European Aquaculture: a multidisciplinary network (LARVANET)” and d) the project “The future of research on aquaculture in the Mediterranean region” which was approved under the 7th Framework Programme of the EU. Other activities of MeMARS in 2010 included the support of private fish farms and the information of students of primary and secondary education on aquaculture in Cyprus.

Regardless the fact that a variety of measures have been undertaken, it must be noted that the exploitation of the abovementioned incentives, grants and research outcomes depends on the willingness, awareness and private initiative of fishermen. Thus the present adaptive capacity of the fishery sector against these alterations can be considered as **Limited to Moderate**.

9.4.2 Fishstock physical environment

9.4.2.1 Assessment of sensitivity and exposure

Sensitivity

Mean sea level is predicted to rise between 10 and 90 centimeters during this century, with most predictions in the range of 30-50 centimeters. This will likely damage or destroy many coastal ecosystems, which are essential to maintaining wild fish stocks, as well as supplying seed to aquaculture. The rise of sea level will affect coastal vegetation and the respective ecosystems in general. Coastal vegetation buffers the shore from storm surges that can damage fish ponds and other coastal infrastructure and may become more frequent and intense under climate change. The sensitivity can be measured by using the following indicators:

- ‘Annual deviations in number of freshwater aquaculture fisheries’,
- ‘Annual deviations shifting number in species abundance’ and
- ‘Changes in production of inshore, offshore and pelagic fisheries systems’.

For the case of Cyprus, there are no available data regarding the correlation among sea level rise and alterations on fishstocks’ physical environment, regarding the sensitivity of fishery sector. Thus, no characterization was given to the sensitivity of fishstock environment to climate change.

Exposure

Higher sea levels are exposing swallow waters to salinization, which is detrimental to freshwater fisheries, aquaculture and limits the income of fishery sector. Along with the negative consequences, however, come benefits in the form of increased areas suitable for brackish water culture of such high-value species as shrimp and mud crab (World Fish

Centre, 2007). The indicators that can measure the exposure of the fishery sector to salinization include:

- 'Surface area available for aquaculture' and
- 'Volume of freshwater availability for aquaculture'.

For the case of Cyprus, there are no available data regarding the correlation among sea level rise and alterations on fishstocks' physical environment, regarding the exposure of fishery sector. Thus, no characterization was given to the exposure of fishstock environment to climate change.

9.4.2.2 Assessment of adaptive capacity

In general, the adaptive capacity measures against alterations on fishstock's physical environment due to sea level rise are referring to the following activities (Food & Agriculture Organization of the United Nations, 2008):

- Provision of alternative livelihoods through aquaculture, building capacity and infrastructure,
- Making greater use of hatchery seed, protecting nursery habitats, developing formulated pellet feeds (higher cost but less environmentally degrading) and developing alternative livelihoods for suppliers,
- Improving monitoring and early warning systems, changing water abstraction points where feasible. In particular, The Oceanography Centre, University of Cyprus, is already adopting and using these systems.

In Cyprus the following measures have been undertaken that can improve the adaptive capacity of fishstock physical environment:

- Construction of Coastal Defense Works
- Development of fishing shelters. Fishing shelters are constructed for the protection of fishing boats against extreme events such as storm and large waves. Currently in Cyprus there are 11 fishing shelters in operation. The following economic incentive is provided by the Operational Programme for Fisheries 2007-2013:
    - Measure 3.3: Fishing ports, landing sites and shelters. This measure promotes operations that have to do with safe fishing vessel positioning in ports as well as hygienic and high quality fisheries products.
- Designation of marine protected areas
  Among the most important tools for the conservation of marine biodiversity and the sustainable development of marine resources is the creation of marine protected areas. The marine protected areas have been designated in order to protect fragile ecosystems, endangered species and in general marine biodiversity. In Cyprus there are six marine protected areas.
- Artificial reefs

Artificial reefs are very important as they provide shelter, food, environment suitable for reproduction, growth and increase in size and number of populations of living marine organisms and of the fishing productivity. The DMFR will create up to 4 artificial reefs in marine areas of Famagusta, Limassol and Paphos. The following economic incentive is provided by the Operational Programme for Fisheries 2007-2013:

  - Measure 3.2: Protection and development of aquatic fauna and flora.
    Measure 3.2 targets the protection and development of the fisheries resources at the coastal fishing areas under particular measures that concern directly the fishing activities. In particular, this measure includes the construction and installation of artificial reefs.

- Measures for the protection of water quality.
  Several measures are foreseen in the water policy of Cyprus in order to attain a good ecological status of all fresh and coastal waters. A monitoring programme for all water bodies has been established in order to access progress of the measures implemented. The policy is compliant with the EU Water Framework Directive as well as with the Directive 91/676/EEC on the protection of waters against point and diffuse pollution caused by nitrates.

With reference to the incentives discussed above, it must be noted that their exploitation depends on the willingness, awareness and private initiative of fishermen. Thus the present adaptive capacity of fishstock physical environment can be considered as **Limited to Moderate**.

9.4.3 Cost implications for fishermen

9.4.3.1 Assessment of sensitivity and exposure

Sensitivity

The fishery is sensitive in extreme events, especially sea storm surges and tidal waves. More sensitive to these events are the infrastructures that refer to aquaculture since they are subjected to damages from these physical phenomena.

In general, extreme events will affect inshore fishery and aquaculture in the following ways:

- Loss of aquaculture stock and damage to or loss of aquaculture facilities and fishing gear,
- Higher direct risk to fishers in terms of capital and insurance costs needed to design cage moorings, pond walls and jetties that can withstand storms.
- Loss of wild and cultured stock,
- Decreased production costs and therefore, loss of opportunity as production is limited,

- Reduced wild fish stocks, intensified competition for fishing areas and more migration by fisherfolk.

Based on the aforementioned indicators that can measure the sensitivity of the fishery sector against extreme events are related with the difficulties in fishing due to storms and/or the presence of large tidal waves. These indicators include:

- 'Deviations in production cost of inshore, offshore and pelagic fishery due to extreme events',
- 'Cost of damages from storm surges on aquaculture'
- 'Cost of maintaining pond water levels and from stock loss'

For the case of Cyprus, there are no available data regarding the correlation among extreme events and their relative impacts on the fishery sector. Thus, no characterization was given to the sensitivity of cost burden to fishermen due to climate change.

Exposure

The fishery sector is exposed to extreme events by the consequences of wave damages to infrastructure or flooding from storm surges.

The exposure of fishery sector against extreme events can be measured by the indicators called:

- 'Cost of damages to freshwater capture fisheries', and
- 'Frequency of storm surges'
- 'Number of fishers migration'

For the case of Cyprus, there are no available data regarding the correlation among extreme events and their relative impacts on the fishery sector. Thus, no characterization was given to the exposure of cost burden to fishermen due to climate change.

9.4.3.2 Assessment of adaptive capacity

In general, the measures that can be undertaken to reduce the cost implications of fisherman due to climate change (and especially extreme events) are the following (Food & Agriculture Organization of the United Nations, 2008):

- Provision of compensatory allowances for income lost due to natural hazards. This is also expected to reinforce fishermen against climate changes as, in this case, they may be more exposed to such extreme phenomena.
- Diversification of production mainly for aquaculture. The diversification of aquaculture production may reduce risk due to reduced productivity of certain less climate resilient fishes by compensating with the increased productivity of some other fishes that may benefit from climate changes.

- Temporary cessation of fishing activities. Under this measure, the beneficiaries shall get aid in case of natural disasters or other exceptional occurrence which pose a hazard to the public health and cause the suspension of fishing activities for a limited time.
- Improving efficacy of water usage, encouraging non-consumptive water use in aquaculture (e.g. culture based fisheries; encourage development of mariculture where possible),
- Using different and faster growing fish species, increasing efficacy of water sharing with primary users (e.g. irrigation of rice paddy), changing species in water basins.
- Shifting to artificially propagated seed (extra cost), improving seed quality and production efficiency, closing the life cycle of more farmed species.
- Encouraging uptake of individual/cluster insurance, improving siting and design to minimize damage, loss and mass escapes, encouraging use of indigenous species to minimize impacts on biodiversity, using nonreproducing stock in farming systems.

In Cyprus the following economic incentives are provided by the Operational Programme for Fisheries 2007-2013:

- Measure 1.2: Temporary cessation of fishing activities. Under this measure, the beneficiaries shall get aid in case of natural disasters or other exceptional occurrence which pose a hazard to the public health and cause the suspension of fishing activities for a limited time.

To this end, the adaptive capacity was characterized as **Limited**.

9.4.4 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of the fisheries sector to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of the fisheries sector against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

"Impacts" and "Adaptive capacity" should be evaluated on the same scale (1-7). For this to be achieved, the square root of "Sensitivity x Exposure" is used. The results of the vulnerability assessment for the fishery sector in Cyprus are summarized in Table 9-5.

Table 9-5: Overall vulnerability assessment of the fisheries sector in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Quantity and Diversity of Fishstocks	Not evaluated	Not evaluated	Limited to Moderate (2)	-
Fishstock Physical Environment	Not evaluated	Not evaluated	Limited to Moderate (2)	-
Cost implications for fishermen	Not evaluated	Not evaluated	Limited (1)	-

In particular, the climatic change impacts that are affecting the fishery sector are characterized by low magnitude potential since the participation of income from fishing as a percentage of GDP is relatively low (~ 0.3%). As for the timing, all impacts that may affect the fishery sector are considered to be observed at a long term basis since they occur gradually. Based on current climate observations of Cyprus, none of the aforementioned impacts can be characterized by high persistence. As for issues related with the reversibility, only impacts from precipitation can be considered as reversible. Sea level rise and changes in inland and sea temperatures, although they are irreversible, they may affect fishery sector at a long term basis.

As for the spatial distribution of climate change induced impacts that are affecting the fishery sector, all impacts occur with the same frequency around the island. The fishery sector is considered as a relatively low vulnerable system due to its importance in GDP terms (low income from fishing as a percentage of GDP).

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10 PUBLIC HEALTH

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Abbreviations and Acronyms

cCASHh project	Climate change and adaptation strategies for human health
CRI	Climate Risk Index
CYSTAT	Statistical Service of Cyprus
DALY	Disability-Adjusted Life Year
ECEH	Regional Office for Europe, European Centre for Environment and Health
EEA	European Environment Agency
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
MANRE	Ministry of Agriculture, Natural Resources and Environment
PWC	Pancyprian Welfare Council
PM	Particulate matter
SES	Socio-economic status
SUDS	Sustainable Urban Drainage Systems
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VBD	Vector-borne diseases
VOCs	Volatile organic compounds
WDD	Water Development Department
WEI	Water Exploitation Index
WHO	World Health Organization

10.1 Climate change and public health

Climate change is now widely recognized as the major environmental problem facing the globe as well as the largest threat to human health (Oygar, 2009). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the warming of global climate system is explicit, characterized by high > 95% certainty that the cause is extrinsic (Hegerl et al., 2007). The IPCC also predicts a chance of 80% that there will be an increase in mortality and morbidity owing to climate change related extreme weather events. In 2007, the 95% of the 16,000 global fatalities from extreme weather effects can be attributed to climate change (GSK/Accenture/SSEE, 2011).

In case of a continuous increase of current emissions, the next generations will face more diseases, deaths related to heat waves and natural disasters, higher rates of climate-related infections and morbidity /mortality associated with allergic and air pollution diseases (Oygar, 2009). There is high confidence according to the IPCC (80% confidence) that in the future the increase in cardio-respiratory morbidity and mortality will be attributed to ground-level ozone (GSK/Accenture/SSEE, 2011).

To date, there is significant evidence that the Mediterranean Basin is already experiencing some of the impacts of climate change including those on public health. The main phenomena that have been recorded in Cyprus are temperature increase (especially during the summer months), an enhance in the frequency and the intensity of heat waves, a reduction in the total precipitation amounts in parallel with increasing rainfall intensity and enhanced drought.

The history of human adaptation and response to climatic factors can be characterized both by great successes as well as disastrous failures. Humans have successfully managed to live in almost every climatic zone on earth despite the fact that regional climatic shifts have affected the development of civilizations and specifically the rise or fall of them (WHO, 2005).

Addressing the health impacts of climate change requires integration of public health and climate change knowledge. Health authorities have expressed concern about climate change and its impact on human health since 1998 and particularly at the World Health Assembly by recognizing that climate change could be a potential threat to human health. At the Third Ministerial Conference for Environment and Health, in 1999, ministers of health and environment for the World Health Organization (WHO) European Region had acknowledged that "human-induced changes in the global climate system and in stratospheric ozone pose a range of severe health risks and potentially threaten economic development and social and political stability". They called for national action by all countries aiming at the immediate reduction and prevention of environmental changes in order to limit the exposure of human populations in Europe to climate change and increased ultraviolet irradiation over the coming decades (WHO, 2005).

In generally terms, climate change can have direct impact to human beings via exposure to hazardous meteorological conditions and indirect impact via vector/rodent/water/or food-borne diseases and allergic disorders (McMichael et al., 2003).

10.2 Baseline situation

10.2.1 Health status and demographics

Cyprus is the third largest island in the eastern part of the Mediterranean. The population in the government-controlled area of Cyprus was estimated at the end of 2011 at 840,407 from which approximately 79% are Cypriots, while the rest are citizens from other countries (CYSTAT, 2011).

It is estimated that in 2011, 16.1% of the population living in the free part of Cyprus were under 15 years of age and 13.3% over 65 (CYSTAT, 2011). The observed demographic changes of the latest years indicate high aging population. Cyprus experiences the 3rd stage of demographic-epidemiology transitional period featured by degenerative diseases related to the age and the way of living. The average age of Cyprus population has been increased given the fact that during 2000-2005 the fertility rate was 2.3 and in 2008 was reduced to 1.5. Also the percentage of children under the age of 15 years was reduced from 25% (1982) to 16.1 (2011) while the percentage of adults over 65 was increased from 10.8% (1982) to 13.3 (2011) (MANRE, 2010; CYSTAT, 2011).

According to data from EU Statistics on Income and Living Conditions (Eurostat, 2009) collected between 2005 and 2008, 16% of Cyprus population was at risk of poverty, the same percentage with the EU27. However, the Cypriot elderly (65 and over) are at higher risk than the average EU citizen in the same demographic group especially for the years 2007 and 2008 (Table 10-1). In 2008, Cyprus had a poverty risk rate for the group aged over 65 of 49% while only Latvia had a higher rate (51%) and Hungary had the lowest rate (4%). According to Andreou and Pashardes (2009) "the very high poverty rate associated with old age in Cyprus is due to the immaturity of the current old age pension system guaranteeing a decent pension to private sector retirees".

Table 10-1: At risk of poverty in Cyprus and EU27 by age group (%), 2005–2008

Age groups	Male				Female				Total			
	2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008
Cyprus, aged 0-17	**14**	**13**	**11**	**13**	**12**	**12**	**12**	**14**	**13**	**12**	**11**	**14**
EU27, aged 0-17	19	19	19	19	19	19	19	20	19	19	19	19
Cyprus, aged 18-64	**10**	**8**	**9**	**9**	**13**	**12**	**13**	**13**	**11**	**10**	**11**	**11**
EU27,	14	14	14	14	15	15	15	15	14	15	15	14

Age groups	Male				Female				Total			
	2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008
aged 18-64												
Cyprus, aged 65+	**47**	**47**	**50**	**43**	**53**	**54**	**54**	**54**	**21**	**21**	**52**	**49**
EU27, aged 65+	16	17	16	16	21	21	21	21	19	19	19	19
Cyprus, Total	**15**	**14**	**14**	**14**	**18**	**17**	**18**	**18**	**16**	**16**	**16**	**16**
EU27, Total	15	15	15	15	17	17	17	17	16	16	16	16

Source: Eurostat, 2009

The standard of health in Cyprus is considered to be very high and compares favourably with that of developed countries, as it is shown by the various health indicators, such as the infant mortality rate which stands at 3.3 per 1.000 live births, the expectation of life at birth with 77.9 years for males and 82.4 for females and the number of persons per doctor at 348, in the year 2009 (CYSTAT, 2012).

Injury, poisoning and certain other consequences of external causes have the highest share, (11.5%) of the total patients discharged from general hospitals, followed by diseases of the circulatory system (9,0%), diseases of the respiratory system (7,9%), diseases of the digestive system (7.6%), neoplasms (6,6%), pregnancy, childbirth and puerperium 6.3% and diseases of the genitourinary system (6.1%). All other disease categories account for the remaining 45.0% (CYSTAT, 2012).

The five leading causes of death for the period 2004-2009 in Cyprus were diseases of the circulatory system, neoplasms, endocrine, nutritional and metabolic diseases, diseases of the respiratory system and external causes of injury and poisoning (Ministry of Health, 2011). Figure 10-1 illustrates the main causes of death in Cyprus for the period 2004-2009.

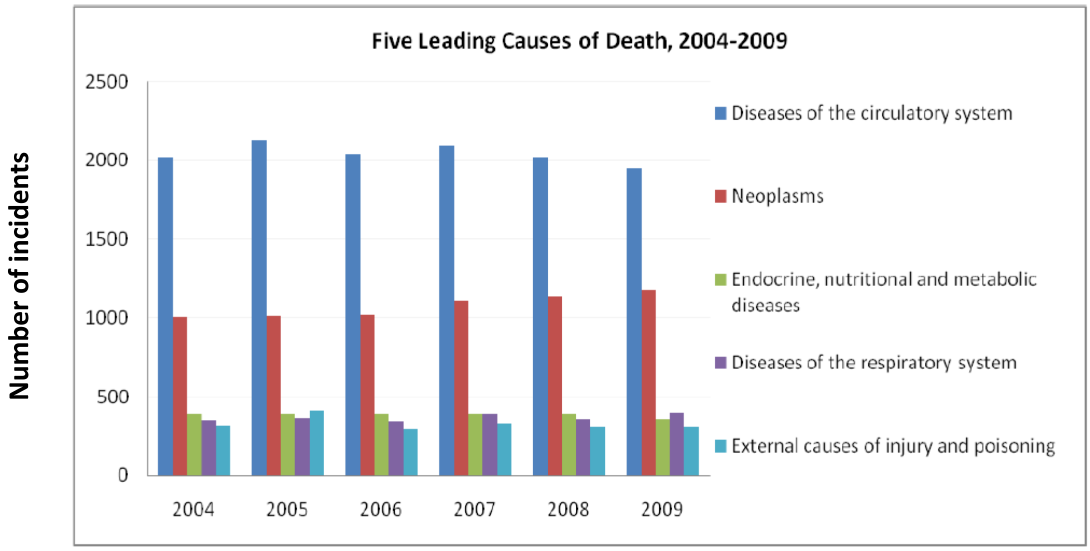


Figure 10-1: Five leading causes of death in Cyprus

Source: Ministry of Health, 2011

The health and demographic indicators of Cyprus are summarized in Table 10-2.

Table 10-2: Health and demographic indicators of Cyprus

Indicators	Values
Number of persons per 1 doctor (2009) Number of persons per hospital bed (2009)	348 263
% Urbanization (2010) % people living in cities greater than 100,000 inhabitants (2009)	69% of total population 48%
Age structure 0-14 years (2011 census) 15-64 years 65 years and over	16.1% 70.6% 13.3%
Birth rate (2009) Death rate (2009)	12 births / 1,000 population 6.5 deaths/ 1,000 population
Infant mortality rate (2009)	3.3 deaths / 1,000 live births
Total fertility rate (2009)	1.5
Life expectancy at birth (2009)	Male: 77.9 Female: 82.4
Health expenditures (2009)	1,190.6 million € (46% in Public Sector, 54% in Private Sector) 6.2% of GDP

Source: CYSTAT, 2012; CYSTAT, 2011

10.2.2 The health care system in Cyprus

As also recognized by the World Health Organization, Cyprus health system is of high standards providing priority to its health care system and actively promoting the preventive medicine. Government hospitals are located in all the major cities. Smaller government-run hospitals and clinics are present in other areas of the country.

The Ministry of Health, the Ministry of Agriculture, Natural Resources and Environment and the Ministry of Labour and Social Insurance jointly are responsible for environmental health. Their responsibilities include monitoring pollution levels, diagnosing, treating and controlling animal diseases, monitoring the level of environmental pollution, monitoring the microbiological quality of drinking water supplies, and other pollution (pesticides and other micro pollutants), monitoring veterinary drug residues in meat and animal products monitoring radioactivity in drinking water, food etc. Jointly they have taken action to improve the existing legislation relevant to protection of the environment. Furthermore, all households in Cyprus have guaranteed access to safe drinking water and efforts have been made to improve the quality of drinking water in accordance with EU regulations. Finally, almost 100% of the population has adequate sewage-disposal facilities (Golna et al., 2004).

In the period 1990-2005, the expenditures on health in Cyprus as percentage of GDP presented a general increasing trend from 4.5% to 6.3% as shown in Figure 10-2.

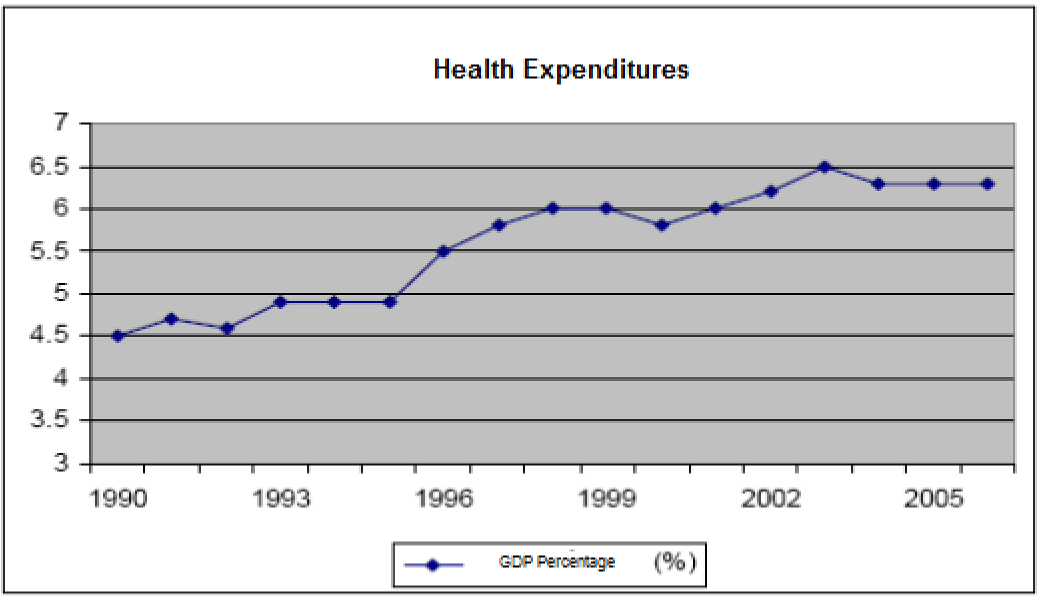


Figure 10-2: Heath expenditures as GDP percentage (1990-2005)

Source: Matsis, 2008

Despite the significant increase in total expenditures of health and the increase in the percentage of GDP being absorbed by the sector, Cyprus compared with other countries spends relatively a small percentage of the GDP for health care. In 2006, Cyprus was ranked 23rd with health expenditure at 6.3% of GDP comparatively to 27 European countries and 53rd universally within 235 countries according to the World Health Statistics 2011 (WHO, 2011)

The rank of Cyprus is mainly attributed to the high age of population in comparison with other European countries. One important feature of the National Health Service of Cyprus is the low percentage of total health expenditure by the public sector (46% of total expenditure in 2009) in comparison with the private sector (54% of total expenditure in 2009), which is a result of the lack of a National Health Scheme. The share of health expenditure in the private sector in the EU-15 countries is around 25% (Golna et. al., 2004; Matsis, 2008).

Cyprus is in the process of implementing a comprehensive National Health Insurance System (NHIS) that is expected to be in place soon. At the moment the government, provides medical insurance to its employees through the public health sector. Employer and trade union sponsored schemes also provide medical insurance to their members, such as those organized by semi-government organizations and large private companies (e.g. banks) that offer health care coverage (including at least in-hospital insurance) to employees and their families. Furthermore, there is the "Government Regular Employees Health Care and Welfare Scheme" administered by trade unions and governed jointly by representatives of the Ministry of Health, workers' unions and others (Golna et. al., 2004).

This situation will change essentially when the NHIS becomes law in the next five years. Under the new regime, the public health system will receive funding from the compulsory health insurance contributions and will also provide comprehensive medical care to the entire resident population at all levels of health care. The NHIS proposed for Cyprus aims at equity in finance and universal provision of health care with efficient delivery, high standards and containment of cost. As long as the patient complies with the system parameters there should be no out-of-pocket cost (Golna et. al., 2004).

Countries in the WHO European Region vary tremendously in their response capacities. The adaptive capacity index of Cyprus is 3, while Greece has 4 and Luxembourg has the highest, of 5. The highest the adaptive capacity index, the more the country is able to adapt in climate change conditions.

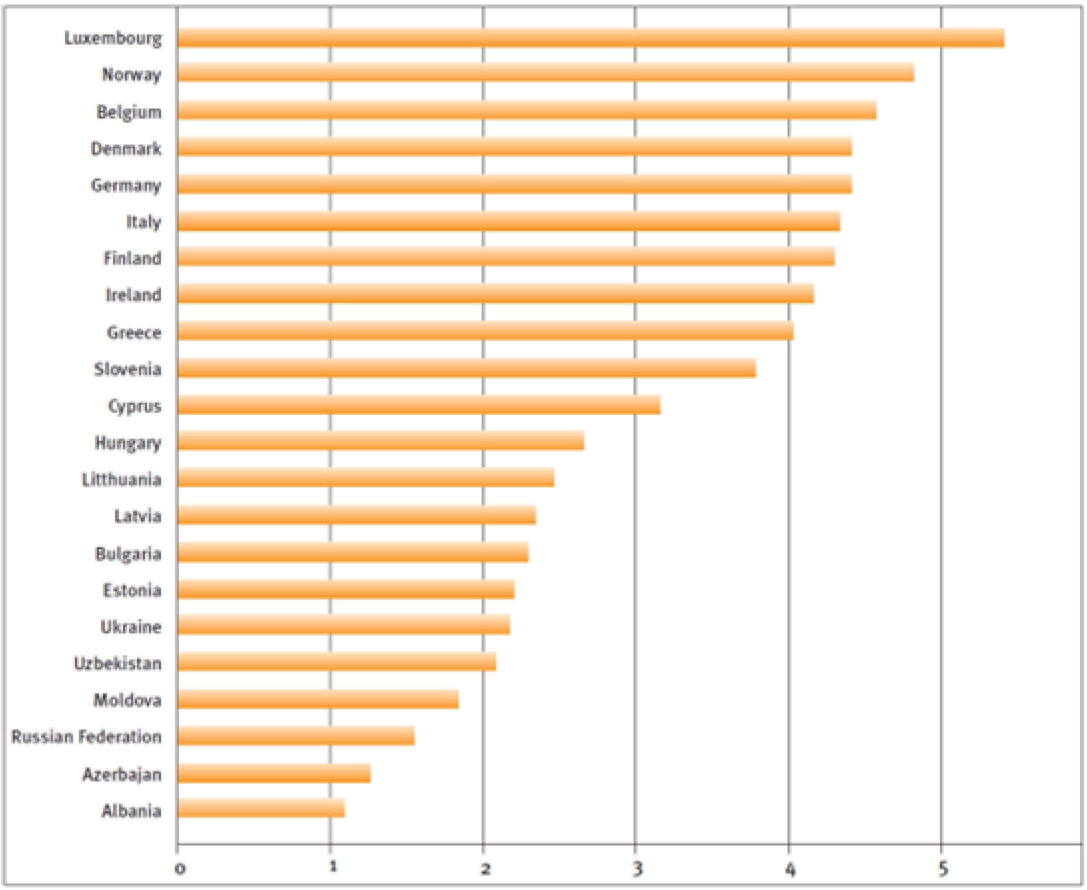


Figure 10-3: Adaptive capacity index for 22 European and Central Asian countries

Source: WHO, 2005

10.2.3 Research on the climate change effects upon public health in Cyprus

Many Institutions and Government Departments in Cyprus are occupied with collection, analysis and study of Climatological Data and their possible health effects: the Meteorological Survey Department, the Environment Service, Ministry of Health, academic departments (University of Cyprus, Cyprus Institute)(Panayiotou, 2009; CDC, 2009).

The international group of climate scientists and epidemiologists, joined by policy analysts, policy makers, statisticians and modelers, has come together under the auspices of the Cyprus Institute and MedCLIVAR ESF (European Science Foundation) programme aiming to coordinate and promote the study of the Mediterranean climate. MedCLIVAR also includes the study of the occurrence of extreme events -closely related to climate variability, climate change impacts as well as the challenges that climate change poses to public health in the Mediterranean and similar climatic regions around the world. In the context of this join, the workshop “Impacts of Mediterranean Climate Change on Human Health” was implemented in order to reinforce collaborations to better understand the challenges and address potential solutions through research aimed at informing health risk mitigation through regional adaptation policies (Paz et al., 2010).

Furthermore, in 2011 the project "Climate Change and Public Health: Assessment of the Effects of Extreme Weather and Development of Innovative Prevention and Mitigation Strategies" of the Research Promotion Foundation was launched. It is expected that its findings will enhance the adaptive capacity of public health to climate changes and in particular to heat waves.

10.3 Impact assessment

Changes in the frequencies of extreme heat and cold, of floods and droughts, and the profile of local air pollution and aeroallergens would affect population health directly. Other indirect health impacts would result from the effects of climate change on ecological and social systems. These impacts would include changes in occurrence of infectious diseases, local food production and under-nutrition, and various health consequences of population displacement and economic disruption (WHO, 2003). However, the effects of climate change on existing environmental and public health problems are difficult to discern. The challenge is to identify their 'additional' effect, i.e., the increase in health problems that can be attributed to climate change as an additional risk factor.

The impacts of climate change and extreme events on human health in Europe have been investigated by a study for the cCASHh project "Climate change and adaptation strategies for human health" and presented in Figure 10-4.

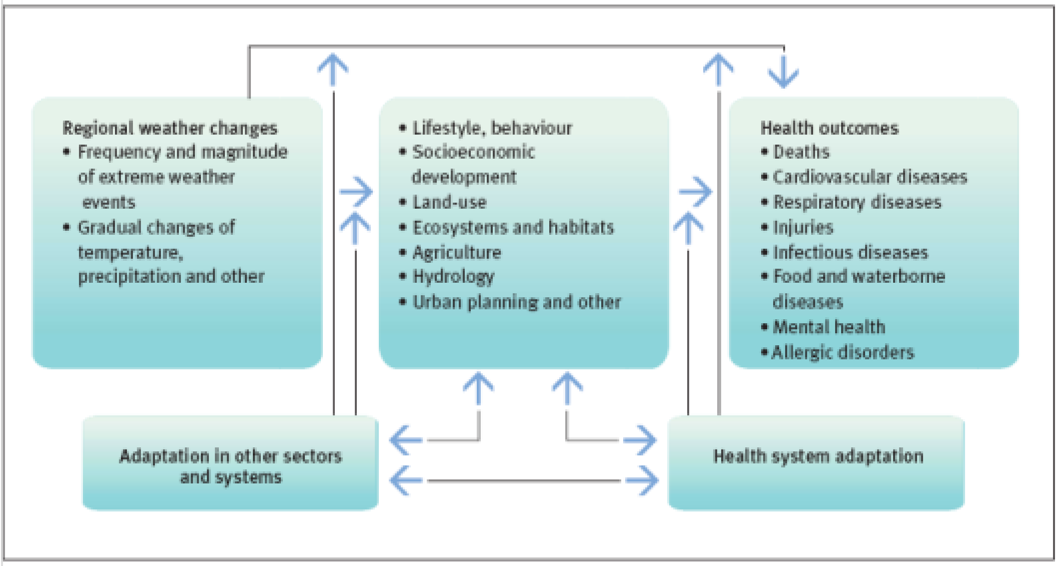


Figure 10-4: The relationship between regional weather changes, exposures and health outcomes

Source: WHO, 2005

The cCASHh project was funded by the European Commission and coordinated by the World Health Organization Regional Office for Europe, European Centre for Environment and Health (ECEH) Rome, studied health impacts and policy implications of heat stress related mortality and morbidity, food-borne (salmonellosis and campylobacteriosis), waterborne diseases and vector-borne diseases. According to the project, in Europe the extreme events are expected to increase in frequency and severity, particularly heatwaves, droughts and intense rainfall events (WHO, 2005).

A summary of the potential impacts of climate change on human health in Cyprus per climate change factor is presented in Table 10-3.

Table 10-3: Relationship between observed climate changes and impacts on the public health sector

Climate change factors	Direct Impacts	Indirect Impacts
High temperatures and heat waves	– Heat related stresses – Deaths due to heat strokes – Cardiovascular diseases – Respiratory and metabolic disorders	– Water-borne diseases due to increased algal blooms – Food-borne diseases due to food contamination – Vector-borne diseases due to the higher risk of transmission and changes in the geographical and seasonal distribution
Increase in the intensity and frequency of extreme events (Floods, storms)	– Deaths and injuries from floods, storms, landslides and fires – Psychological morbidity (mental disorders) from floods, storms, landslides and fires	– Water-borne diseases caused by water contamination and water washed diseases caused by poor sanitation conditions – Vector-borne diseases (malaria, Leishmaniasis, Mosquitos) due to stagnant waters – Diarrhoea diseases (including cholera) – Reduced nutritional status
Droughts	– Deaths and injuries from fires caused by high temperatures combined by strong winds and drought	– Vector-borne diseases owing to changes in vector transmission and contamination of small rivers and drainage canals – Water-borne diseases – Respiratory diseases due to increased air-borne particulate matter – Child malnutrition and under-nutrition, due to loss of agricultural production
Air pollution		– Eye irritation – Respiratory tract irritation – Exacerbation of respiratory diseases – Exacerbation of asthma and irritation of bronchi – Exacerbation of allergic rhinitis, asthma and other atopic diseases

The climate change impacts on public health which are analyzed in this chapter were categorized as follows:

Direct impacts: 1. Deaths and health problems related to heat waves and high temperatures, 2. Deaths and injuries from floods/storms, 3. Deaths and injuries from landslides and 4. Deaths and injuries from fires.
Indirect impacts: 1. Vector-borne and rodent-borne diseases, 2. Water- borne and food-borne diseases, 3. Climate-related effects upon nutrition, 4. Air pollution related diseases.

10.3.1 Deaths and health problems related to heat waves and high temperatures

According to the IPCC (2007), hot days, hot nights and heatwaves have become more frequent. Additionally, IPCC ascribes by 50 per cent the increase of heat wave related deaths to climate change, and expresses an 80 per cent level of certainty that increasing temperatures will have a negative impact on health. For each 1°C rise in temperature above a specified ceiling (which varies by region) death rates are predicted to rise by between one per cent and four per cent. This prediction is in accordance with observations in cities of Mediterranean Basin which have shown that heat waves can have very strong effects on mortality, reporting an increase of 1-4% for each degree of temperature raise (GSK/Accenture/SSEE, 2011).

On the contrary, there is another opinion that the mortality impact of a heat wave is uncertain in terms of the amount of life lost; a proportion of deaths occur in susceptible people who were likely to have died in the near future. Nevertheless, the certainty that the increase in the frequency and intensity of heat waves can increase the numbers of additional deaths from hot weather remains high. Exposure to extreme and prolonged heat is associated with heat cramps, heat syncope, heat exhaustion and heat stroke. Nonfatal impacts of heat waves are heat stroke and heat exhaustion (Faunt et al., 1995; Semenza et al., 1999). Deaths from heat stroke may be underreported because heat stroke is similar to other more familiar causes of death, especially coronary or cerebral thrombosis, once the body is no longer hot itself or in a hot environment (Keatinge et al., 1986; Mirchandani et al., 1996).

The primary concern in Europe as well as in Cyprus is linked to heat-related mortality and morbidity, due to increases in maximum temperature and more frequent heat waves, although these issues are also influenced by socio-economic changes due to population growth, the increased average age distribution in Cyprus and migration. In addition, mortality is associated to the timing of heat waves as heat-waves early in the summer are associated with higher mortality than late season heat-waves (WHO, 2005).

Changes in climate have implications for occupational health and safety. Heat stress due to high temperature and humidity is an occupational hazard that can lead to death or chronic ill health from the after-effects of heatstroke. Both outdoor and indoor workers are at risk of heatstroke. The occupations most at risk of heatstroke, include construction and agriculture/forestry/fishing work. Considering the fact that a high percentage of immigrants laborers, work in outdoor environments, the risk for the particular vulnerable group is high.

During the 2003 European heat wave, the highest temperature was recorded in Cyprus. In the capital, Nicosia, temperatures unofficially exceeded 57 °C while temperatures usually reach 45°C during the summer period. Many people reported such temperatures on their thermometers in their houses. The official record was 52.1 °C in urban Nicosia. As a result of deaths and high temperatures, the government had to recommend a 3 day curfew between 11am and 5pm (Absolute Astronomy).

However, there are no sufficient data for estimating whether there is an increasing trend on the incidents of heat related deaths and health problems which could be associated with climate changes in Cyprus.

10.3.2 Deaths and injuries from floods/storms

The frequency and intensity of extreme weather events such as heavy rainfall, storms and floods are anticipated to increase having immediate effects such as deaths and injuries caused by drowning and being swept against hard objects.
Generally, the exposure to high-frequency flooding events can result in long-term problems such as increased rates of anxiety and depression stemming from the experience itself, troubles brought about by geographic displacement, damage to the home or loss of family possessions. Moreover, the persistence of flood-related health effects is directly related to flood intensity (WHO, 2005).

There is increasing evidence of the importance of mental disorders as an impact of disasters (Mollica et al., 2004; Ahern et al., 2005). A systematic review of post-traumatic stress disorder in high income countries found a small but significant effect following disasters (Galea et al., 2005). There is also evidence of mediumto long-term impacts on behavioural disorders in young children (Durkin et al., 1993; Becht et al., 1998; Bokszczanin, 2000).

Although there is a record of historical floods in Cyprus dating back to 1859-2011, the data were not considered sufficient to make an assessment for an increasing trend in deaths and injuries from floods as it is during the last years that the recording is being made more systematically. Indicatively, the recorded flooding events in Cyprus where people were injured or killed during the period 1970-2011 are presented in Figure 10-5.

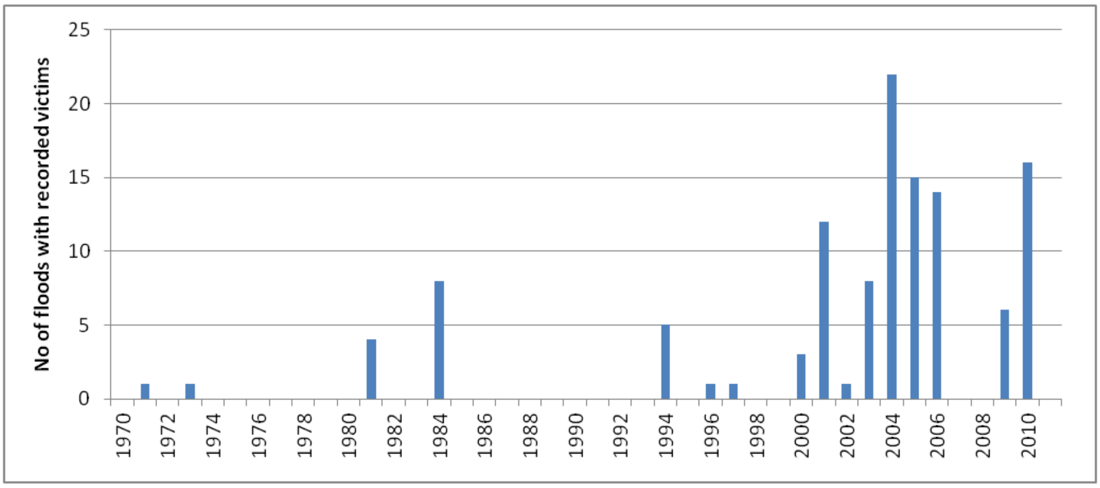


Figure 10-5: Number of flooding events with recorded victims in Cyprus (1970-2011)

Source: WDD, 2011

10.3.3 Landslide-related deaths and injuries

An increase in extreme rainfall events is expected to increase landslide risk (Confaloniery et al., 2007). Landslides may directly affect people by causing deaths and injuries but also may have after affects such as mental disorders caused by the experienced shock, the grief felt by the loss of relatives and friends, the damage to the home or loss of family possessions. In addition, landslides may result in the displacement of communities and migration. However, there is no official record in Cyprus of victims affected.

10.3.4 Fire- related deaths and injuries

Climate change is expected to increase the risk of forest and rural fires. In particular, forest fires in Cyprus are considered a major and permanent threat causing enormous damage to forest ecosystems and in some cases threaten residential regions (Alker, 2009).

Forest and bush fires may cause deaths of people trapped in them, burns and other injuries. Large fires are also accompanied by an increased number of patients seeking emergency services (Hoyt and Gerhart, 2004).

Taking into account certain features characterizing Cyprus such as high temperatures, prolonged and severe drought periods, strong winds and the configuration of the ground and extremely flammable vegetation, the fire risk is high.

Other parameters which contribute to an increased fire risk are the accumulation of biomass due to the abandonment of rural areas and the increasing tourism and exodus of city residents to forested areas.

However, there are no sufficient data for estimating whether there is an increasing trend on the incidents of fire- related deaths and injuries which could be associated with climate changes in Cyprus.

10.3.5 Vector-borne and Rodent-borne diseases

Vector-borne diseases (VBD) are infections transmitted by the bite of infected arthropod species, such as mosquitoes, ticks, triatomine bugs, sandflies and blackflies. VBDs are among the most well-studied diseases associated with climate change, due to their widespread occurrence and sensitivity to climatic factors.

The transmission of some mosquito-borne diseases is affected by drought events. During droughts, mosquito activity is reduced and, as a consequence, the population of non immune persons increases. When the drought breaks, there is a much larger proportion of susceptible hosts to become infected, thus potentially increasing transmission (Bouma and Dye, 1997; Woodruff et al., 2002). In other areas, droughts may favour increases in mosquito populations due to reductions in mosquito predators (Chase and Knight, 2003). Other drought related factors that may result in a short-term increase in the risk for infectious disease outbreaks include stagnation and contamination of drainage canals and small rivers. In the long term, the incidence of mosquito-borne diseases such as malaria decreases because the mosquito vector lacks the necessary humidity and water for breeding.

Although several models predicted a potential increase of malaria in Europe, there is agreement that the risk is very low under current socioeconomic conditions (WHO, 2005). A number of recent modeling efforts has shown that changes in temperature and precipitation could alter the geographic distribution and intensity of malaria transmission (Parry et al., 2001; Martens and Hall, 2000). Projected changes include an expansion in latitude and altitude, and, in some regions, a longer season during which malaria may be present. Such changes could dramatically increase the number of people at risk. In the early part of the twentieth century, malaria was endemic in many parts of southern Europe, but its prevalence was reduced primarily via improved land drainage, better quality of housing construction and higher levels of socioeconomic development, including better education and nutrition. Any role that climate played in malaria reduction would have been small (WHO, 2005).

According to United Nations Environment Programme data (UNEP), there have been no recent deaths in Cyprus due to malaria. However, Cyprus' geographical location makes it more vulnerable for another epidemic. It is documented by WHO that in the future, malaria could move to the Northern part of Cyprus from Turkey, considering the fact that after the Gulf war malaria was spreaded over the boarders into Turkey and the Eastern Mediterranean (Cosmatos, 2009). Important vector populations in Cyprus include malaria-bearing mosquitoes and potentially Schistosome-spreading snails that can be attributed to the mass immigration of refugees from endemic regions (Alker, 2009).

Leishmaniasis is a sendfly-born disease endemic to Cyprus, with a high prevalence of human visceral Leishmaniasis. As climate changes, new species, such as L. tropica may colonize Cyprus, as well as the drug-resistant L. Infantum (Alker, 2009; Dujardin et al., 2009). In addition, West Nile Virus (WNV) which is a Flavivirus transmitted through bird-feeding mosquitoes, has had reported cases in Cyprus. The epidemic potential of this virus begins from 20^{o}C while it reaches its peak at 40^{o}C (Alker, 2009).

Rodent-borne diseases are zoonoses that are transmitted directly to humans by contact with rodent urine, feces, or other body fluids. Rodents are principle hosts for arthropod vectors such as fleas and ticks. Environmental factors that affect rodent population dynamics include unusually high rainfall, drought and introduction of exotic plant species. Rodent-borne pathogens are affected indirectly by ecological determinants of food sources that affect rodent population size (Confalonieri et al., 2007). The rodent-borne diseases that are associated with flooding include leptospirosis, tularaemia and viral hemorrhagic diseases. Other diseases associated with rodents and ticks include plague, Lyme disease, tick borne encephalitis (TBE) and Hantavirus pulmonary syndrome (HPS) (McMichael et al., 2003).

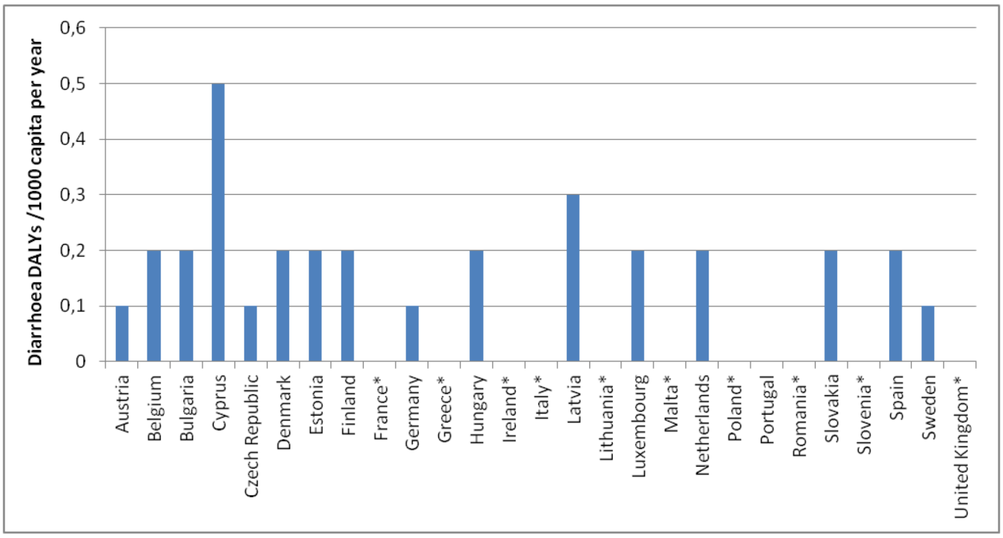
10.3.6 Water-borne and food-borne diseases

Water-borne diseases are likely to increase with climate changes in Cyprus such as decreased rainfall, increased temperature, increase in the frequency of extreme weather events (droughts, heavy rainfall, floods) since drinking water maybe put at risk of contamination.

Water-related diseases can be classified into those caused by ingestion of contaminated water and those caused by lack of hygiene. During drought and flooding conditions water can be contaminated with pathogens while water scarcity creates opportunities for transmission of theses pathogens, due to inadequate hand-washing and personal hygiene. Increased faecal bacteria contamination is also likely to affect drinking water intakes (Symeou, 2009). Higher water temperatures may result in increased occurrence of harmful algal blooms, thus deteriorating the quality of water. Organisms directly transmitted via contaminated water include Escherichia coli, Cholera, Salmonella, hepatitis A and E, poliomyelitis, Giardia lamblia and Entamoeba histolytica. Flooding may also lead to contamination of waters with dangerous chemicals, heavy metals or other hazardous substances, from storage or from chemicals already in the environment (e.g., pesticides). However, as in high income countries there is a number of measures in place such as sanitation and drainage systems, they are less vulnerable to the transmission of water-borne diseases.

Contamination of food may be induced by higher temperatures (surface and ocean) which enhance the survival and proliferation of viruses, bacteria and pathogens in foodstuffs (McMichael et al., 1996).

The estimated number of "healthy" life years lost (DALYs) attributable to water, sanitation and hygiene for 16 Member States of the EU27, shows that Cyprus is in the first place (reference year 2002)(Figure 10-6).



** No data available*

Figure 10-6: Estimated DALYs/1000 capita attributable to water, sanitation & hygiene in the EU27 (2002)

Source: WHO, 2007

The recorded incidents of salmonellosis in Cyprus for the period 1984-2007 present a general increasing trend, although they remain quite below the average respective values in the EU (Figure 10-7).

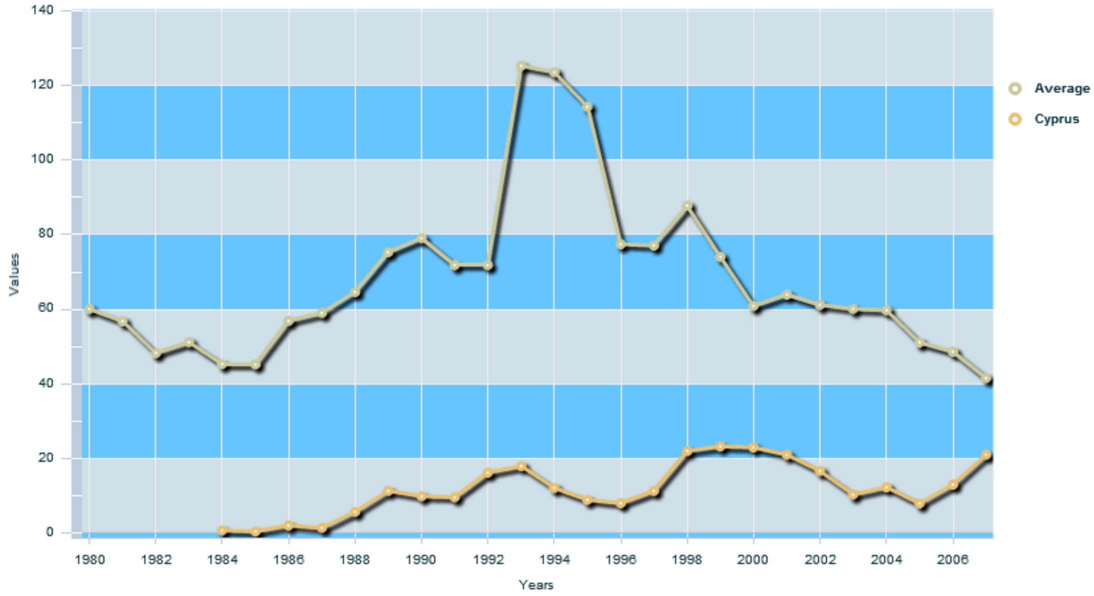


Figure 10-7: Incidence of salmonellosis per 100,000 of population in Europe and in Cyprus (1980-2007)

Source: Heidi tool (EC)

Incidents of Hepatitis A in Cyprus are quite low (less than 1 incident/100,000 capita per year) for the period 1980-2007 while the respective value for the EU was significantly higher until recently when it declined (Figure 10-8).

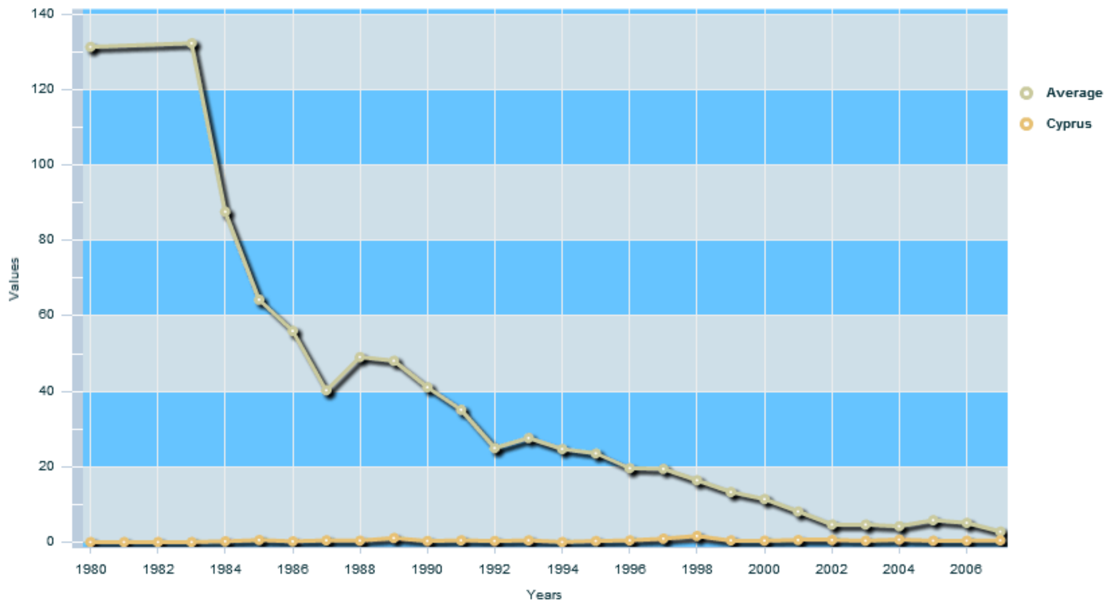


Figure 10-8: Incidence of Hepatitis A per 100,000 of population in Europe and in Cyprus (1980-2007)

Source: Heidi tool (EC)

10.3.7 Climate-related effects upon nutrition

The causal chains through which climate variability and extreme weather influence human nutrition are complex and involve different pathways such as water scarcity, salinisation of agricultural lands, destruction of crops through flood events, wind storms, frosts and hail, disruption of food logistics through disasters, and increased burden of plant infectious diseases or pests (Confalonieri et al., 2007).

Reduced food production may lead in diminished dietary diversity, reduction in overall food consumption and in malnutrition, especially in low-income countries. Both acute and chronic nutritional problems are associated with climate variability and change. Malnutrition increases the risk both of acquiring and of dying from an infectious disease. Drought and the consequent loss of livelihoods is also a major trigger for population movements, particularly rural to urban migration.

During drought years in Cyprus, the agricultural sector is the first to receive water cuts as it consumes approximately 60% of total water demand. Irrigation water is rationed with priority to permanent crops then to green houses while seasonal crops are allocated with a very small amount of water. As a consequence, significant reductions in farmers' yields are recorded and especially in seasonal crops such as vegetables and potatoes.

In absence of data related to the quantities of damaged crops in Cyprus due to extreme climatic phenomena and their impact upon nutrition, the amounts of compensation paid to the farmers may be used to access indirectly the damages to crop yields. The loss of crop yields are associated with climatic factors such as frosts, droughts, heat waves, wind storms, hail and floods are presented indicatively (Figure 10-9 and Figure 10-10). Assuming that the amount of compensation provided is directly related to the crop areas destructed, the greatest climatic threats for the agricultural production and subsequently for food availability, are frosts and droughts.

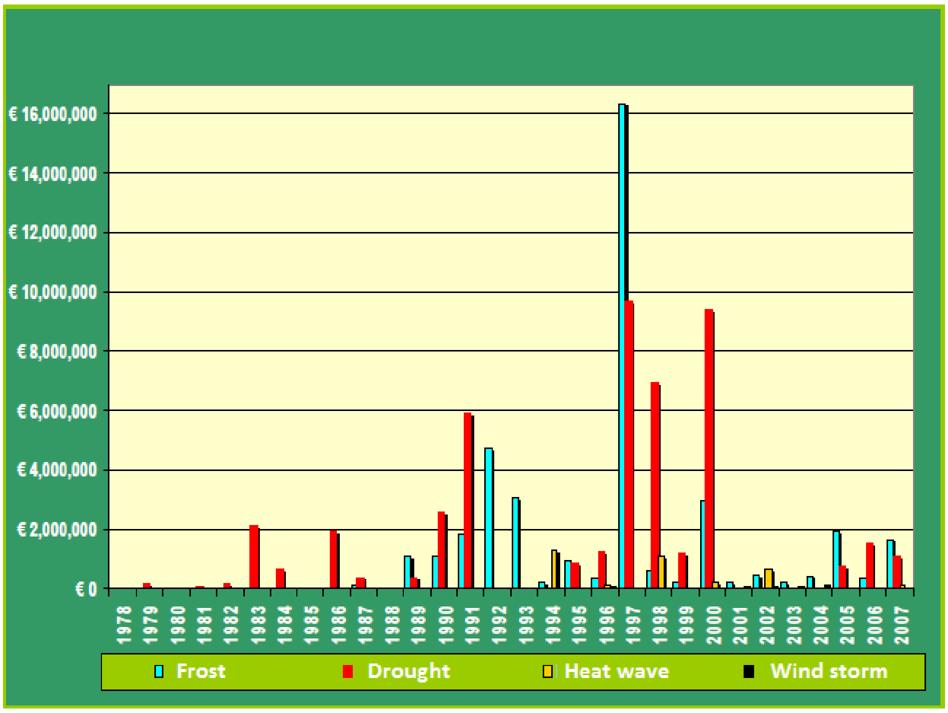


Figure 10-9: Compensation provided for damages to crops caused by frost, drought, heat wave and wind storm in Cyprus (1978-2007)

Source: Pashiardis, 2011

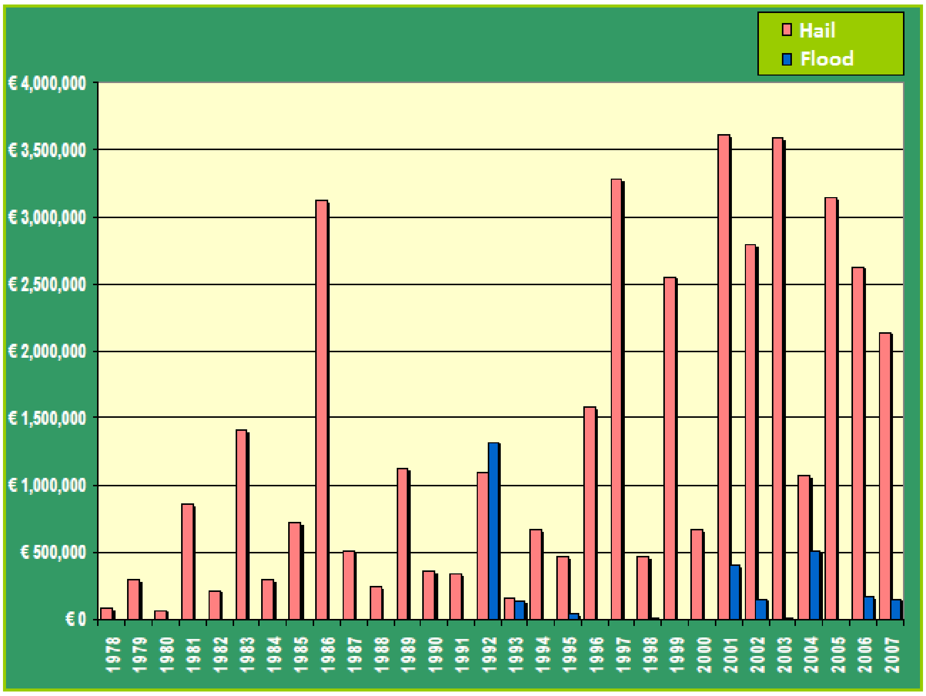


Figure 10-10: Compensation provided for damages to crops caused by hail and flood in Cyprus (1978-2007)

Source: Pashiardis, 2011

The severity of the impact is however associated with the degree of dependence of the population on its agricultural production for satisfying its nutritional requirements.

10.3.8 Air pollution-related diseases

The diseases related to air pollution include exacerbation of respiratory diseases, tract irritation, exacerbation of asthma, irritation of bronchi, atopic diseases, exacerbation of allergic rhinitis, eye irritation. The air pollution health risks related to climate change are caused primarily from the increased concentrations in the atmosphere of particulate matter and ozone. Tropospheric ozone O_3 is the major pollutant being related to climate change while ground-level ozone (smog), though less concentrated than ozone aloft, is more of a problem because of its health effects. During heat-waves, the atmospheric conditions contribute to increases of tropospheric ozone and particulates leading to mortality incidents.

Ambient air pollutants such as nitrogen dioxide (NO_2), ozone, particulate matter (PM), and components of PM including organic carbon and volatile organic compounds (VOCs) have been linked with increased allergic disease and asthma. Ground-level ozone exposure also exacerbates asthma, can damage lung tissue, as shown in increased emergency department visits and hospitalizations. Ozone exposure may also cause new-onset asthma (Oygar, 2009).

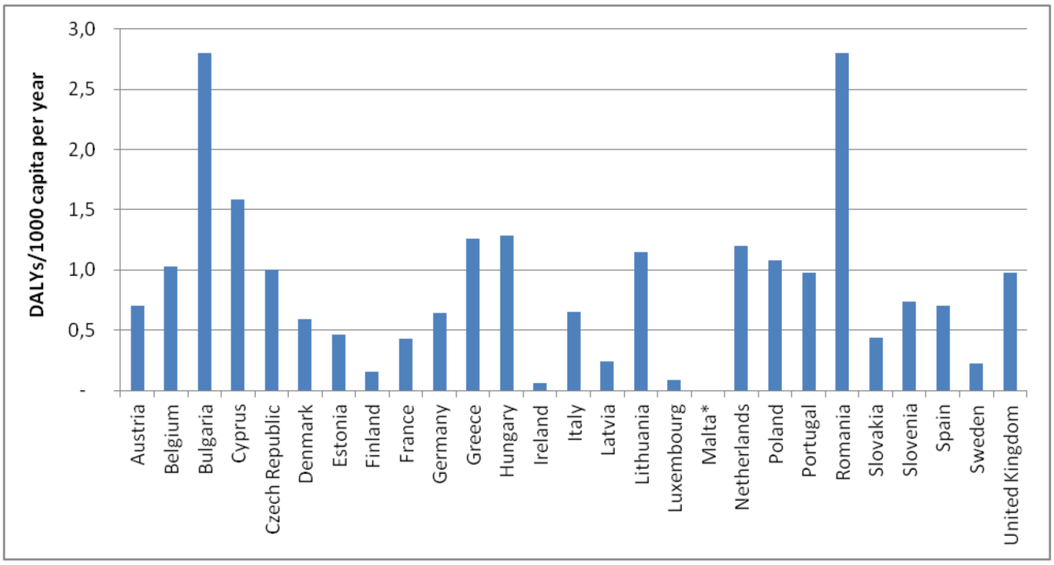
Toxic gaseous and particulate air pollutants released from forest fires into the atmosphere, can significantly contribute to acute and chronic illnesses of the respiratory system, particularly in children, including pneumonia, upper respiratory diseases, asthma and chronic obstructive pulmonary diseases (WHO, 2002; Bowman and Johnston, 2005; Moore et al., 2006).

According to the Preliminary Assessment of Ambient Air Quality in Cyprus (2007) the ozone level shows high values in high elevated background areas like in Troodos mountains while in the cities its concentrations are lower than in the background. The particulate matter PM10 originate from Sahara dust events and anthropogenic activities mainly traffic (Department of Labour, 2007).

Due to the dry climate in Cyprus, Particulate Matter PM10 is re-suspended from soils and other surfaces. The wash out of particles from the air occurs only in winter and spring time when it is raining in Cyprus.

Increased temperature rates and humidity in Cyprus can increase pathogen prevalence in air. According to the Meteorological Service of Cyprus relative humidity of the air is on average between 65% and 95% in winter and between 40% and 60% in summer (Meteorological Service - Climate of Cyprus). An increase in summer humidity would drastically increase the biological disease potential in the air. Additionally, pollutants from forest fires in Cyprus can effect air quality for thousands kilometers (Sapkota et al., 2005).

As it can be seen from Figure 10-11, in 2002 Cyprus had the 3rd highest value of DALYs among the EU27 Member States (excluding Malta), with only Bulgraria and Romania having higher DALYs.



** No data available*

Figure 10-11: Estimated DALYs attributable to outdoor air pollution in the EU27

Source: WHO, 2007

10.4 Vulnerability assessment

In this section, the vulnerability of public health to climate change impacts is assessed in terms of its sensitivity, exposure and adaptive capacity, based on selected indicators and on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which water resources are affected by climate changes, exposure is the degree to which water resources are exposed to climate changes and their impacts while the adaptive capacity is defined by the ability of water resources to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The indicators used for the assessment of sensitivity, exposure and adaptive capacity of Cyprus public health to climate change impacts are summarized in Table 10-4.

Table 10-4: Indicators used for the vulnerability assessment of climate change impacts on Cyprus public health sector

Vulnerability Assessment	Selected Indicators
Heat waves and heat related impacts on human health	
Sensitivity	- Proportion of vulnerable population groups - Percentage of population living in urban areas - Percentage of population living in areas with high humidity
Exposure	- Risk period for heat waves (number of months) - Number of people affected or killed during heat waves - Number of days with maximum temperature over 40°c for the period 1961-2000s - Percentage of population exposed to heat waves and magnitude of heat wave - Geographic distribution of heat wave hazard and population density
Adaptive capacity	- Warning systems providing forecasts of high temperatures (heat stress conditions) through mass media (television, radio and public web sites) - Curfew, prohibition of outdoor work during the high risk hours/days - Houses, indoor public areas and communal centers fully air-conditioned
Floods/storms related deaths and injuries	
Sensitivity	- Proportion of vulnerable population groups

Vulnerability Assessment	Selected Indicators
Exposure	- Geographic distribution of flood hazard and population density - Percentage of population exposed to floods and magnitude of floods - Impact of flooding events on public health
Adaptive capacity	- Civil preparedness and defense force - Health care system - Drainage system for stormwater - Identified of high flood risk areas
Landslide- related deaths and injuries	
Sensitivity	- Proportion of vulnerable population groups
Exposure	- Geographic distribution of landslide hazard and population density - Total number and percentage of the population exposed to landslides by level of intensity
Adaptive capacity	- Civil preparedness and defense force - Health care system - Relocation of landslide prone communities - Landslide protection works - Study of landslides in areas of Paphos District'
Fire-related deaths and injuries	
Sensitivity	- Proportion of vulnerable population groups
Exposure	- Number of people killed or injured during fire events * - Geographic distribution of fire risk areas and population density
Adaptive capacity	- Civil preparedness and defense force - Health care system - Fire brigade - Fire prevention, pre-suppression, detection and suppression measures
Vector-borne and Rodent diseases	
Sensitivity	- Proportion of vulnerable population groups - Percentage of the population with access to sanitation

Vulnerability Assessment	Selected Indicators
Exposure	- Periods of increased temperatures and prolonged droughts - Number of recorded mosquito species - Rate of vector-borne diseases
Adaptive capacity	- Mosquito surveillance program - Diagnosis and treatment, vaccination, vector control, reservoir host control, information and health education as well as disease surveillance and monitoring
Water-borne and food-borne diseases	
Sensitivity	- Proportion of vulnerable population groups - Percentage of the population with access to sanitation - Percentage of the population with access to safe water
Exposure	- Quarantine Law on the notification of communicable diseases - Number of cases of infectious diseases notified - DALYs attributable to water, sanitation and hygiene - Recorded incidents of salmonellosis in Cyprus - Recorded incidents of Hepatitis A
Adaptive capacity	- Food-borne Disease Surveillance System - Monitoring of pollution levels - Monitoring of the environmental pollution level of drinking water supplies - Controls on food and water samples for ensuring quality and safety - Monitoring compliance with state legislation on food safety and quality
Climate-related effects upon nutrition	
Sensitivity	- Proportion of vulnerable population groups
Exposure	- Losses in agricultural production due to extreme events - Dependence of the population on its agricultural production for satisfying its nutritional requirements
Adaptive capacity	- Measures to secure water availability for irrigation in periods of droughts - Measures for the protection of crops from extreme climatic events - Ability for food imports - Safeguarding the production and distribution of food products
Air pollution related diseases	

Vulnerability Assessment	Selected Indicators
Sensitivity	- Proportion of vulnerable population groups
Exposure	- Geographic distribution of ozone concentration and population density - Geographic distribution of PM10 and population density - Geographic distribution of nitrogen dioxide and population density - Humidity - Rate of environmental burden of disease by category of air-related diseases
Adaptive capacity	- Measures for air pollution mitigation

*There were no data regarding this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

In the sections that follow, the vulnerability is assessed for each of the impact categories presented in Section 10.3:

1. Deaths and health problems related to heat waves and high temperatures
2. Deaths and injuries from floods/storms
3. Landslide-related deaths and injuries
4. Fire- related deaths and injuries
5. Vector-borne and Rodent-borne diseases
6. Water-borne and food-borne diseases
7. Climate-related effects upon nutrition
8. Air pollution-related diseases

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability. In case additional data are provided by the competent authorities of Cyprus, the vulnerability of the sector could be re-assessed.

10.4.1 Deaths and health problems related to heat waves and high temperatures

10.4.1.1 Assessment of sensitivity and exposure

Sensitivity

Local factors, such as climate, topography, heat-island magnitude, income, and the proportion of elderly people, are important in determining the underlying temperature–mortality relationship in a population (Curriero et al., 2002; Hajat, 2006).

The population groups that are most vulnerable to heat waves are the elderly, persons with pre-existing chronic diseases, people confined to bed, children, population groups with low socio-economic status, workers in outdoor environments.

In Cyprus, senior citizens (>65 years) represent 13.3% of the total population (CYSTAT, 2011). They are mostly sensitive to direct climate change effects such as thermal stress during heat waves and health stress during other extreme weather events. The elderly population can face unequal access to healthcare, as they are often unable to travel long distances to the nearest health facility. Children (<14 years), which represent 16.1% of Cypriot population (CYSTAT, 2011), is another high-risk group to heat waves because they do not have fully developed temperature regulation mechanisms and are unable to change their environments without help from adults. The very young are at higher risk of death while older children have more heat stress due to time spent in exercise – playing outdoors. Therefore, about 30% of Cyprus population can be characterized as sensitive to heat waves, without taking into consideration parameters such as socio-economic status, health status and standards of living.

Moreover, heat waves have a much bigger health impact in cities than in surrounding suburban and rural areas (Kilbourne, 1997; Rooney et al., 1998). In the urban areas where the air pollution levels are elevated, heat waves are more frequent. In addition to this, the increases in temperatures would be higher in the interior than on the coast of Cyprus which leads to higher adverse health implications on the population living inland. Considering the high percentage of total population in Cyprus living in urban areas (about 70%), the risk of heat waves remains high (McMichael et al., 2001) In addition, a large percentage of the urban population is located in the coastal cities Cypriots, where the high humidity level combined with heat waves increases the vulnerability of population and the risk of mortality and morbidity.

Taking into consideration the aforementioned indicators, the sensitivity of public health in Cyprus to heat waves is considered as **high**.

<u>Exposure</u>

Generally, the risk period for heat waves in Cyprus is identified during the whole summer, that is, from June to August (three months).

According to the international disaster database of the Centre for Research on the Epidemiology of Disasters (CRED, 2011), during three heat wave events that were recorded in Cyprus, a total of 61 people were killed while another 500 people were affected.

As it can be seen from Figure 10-12, the number of days with maximum temperature over 40°C for the period 1961-2000 is presenting a general increasing trend in Nicosia, meaning that people are increasingly exposed to heat waves during the last decades.

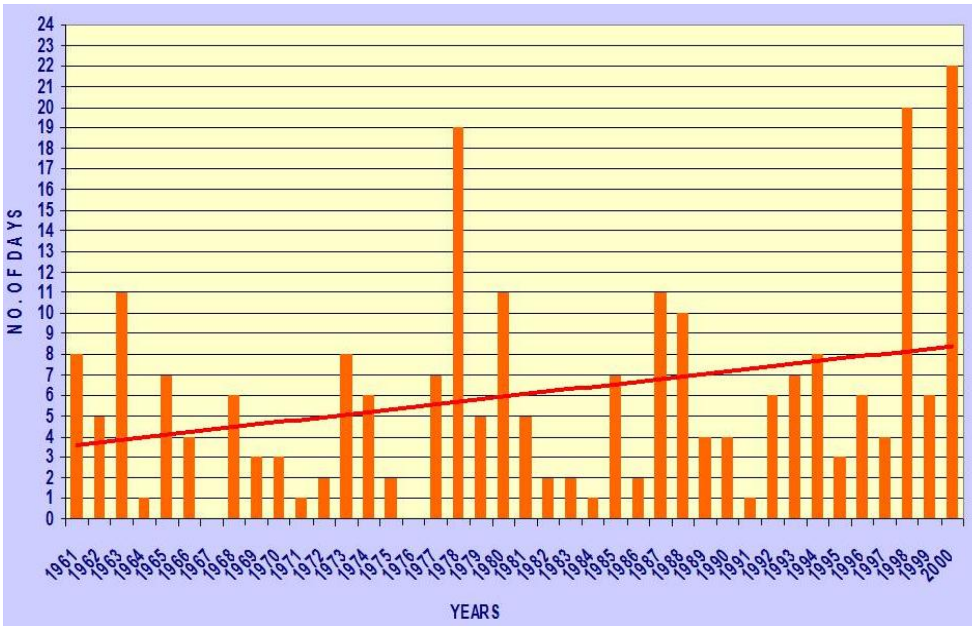


Figure 10-12: Number of days with maximum temperature ≥ 40 °C, Nicosia (1961-2000)

Source: Cyprus Meteorological Service

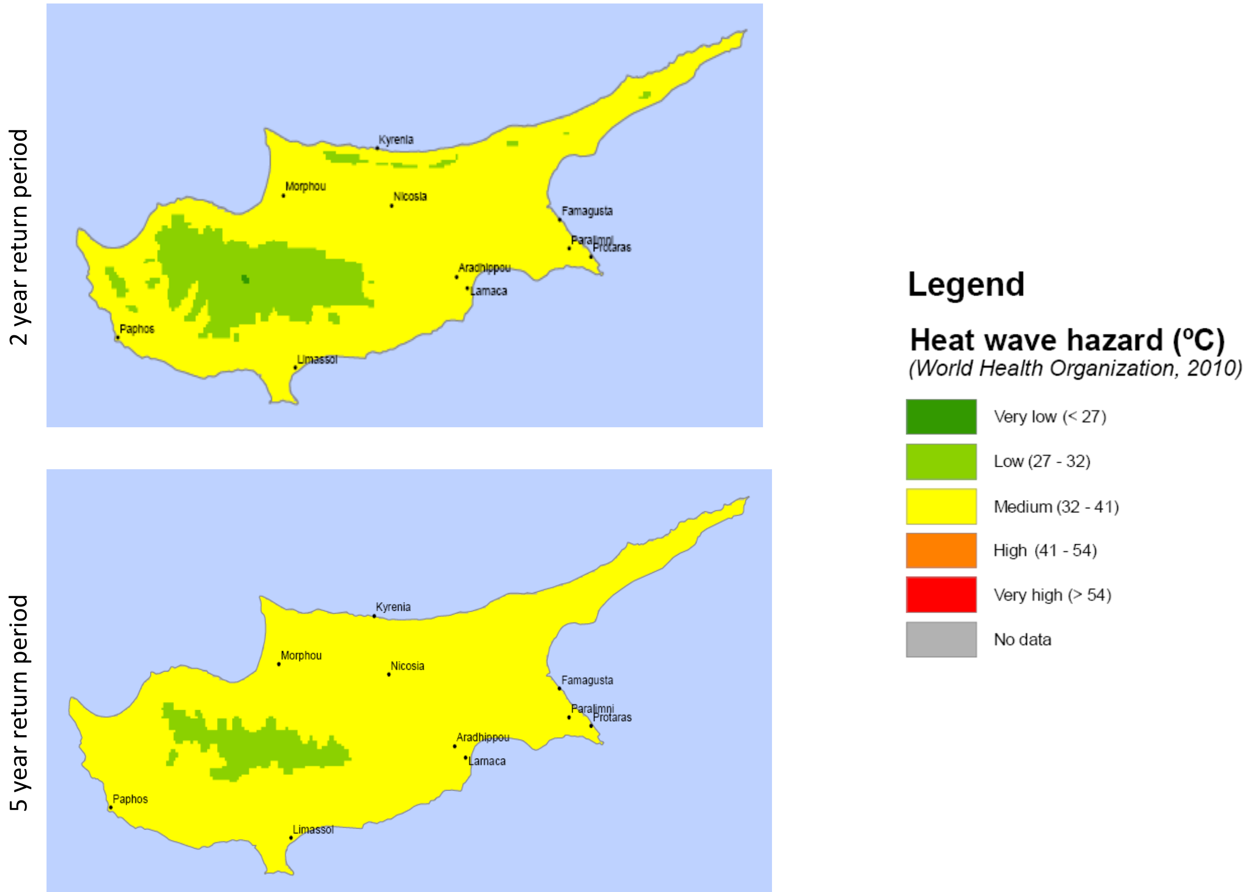
According to WHO (2010), almost 100% of the population in Cyprus is exposed to moderate heat wave hazard (Table 10-5).

Table 10-5: Total number and percentage of the population exposed to heat waves by level of intensity for Cyprus

Return period	Very high No. exposed (%)	High No. exposed (%)	Medium No. exposed (%)	Low No. exposed (%)	Very low No. exposed (%)	No data No. exposed (%)
Heat wave (2 Years)	0 (0.00%)	0 (0.00%)	869519 (98.84 %)	10192 (1.16%)	12 (0.00%)	0 (0.00%)
Heat wave (5 Years)	0 (0.00%)	0 (0.00%)	876547 (99.64 %)	3176 (0.36%)	0 (0.00%)	0 (0.00%)
Heat wave (10 Years)	0 (0.00%)	0 (0.00%)	877279 (99.72 %)	2444 (0.28%)	0 (0.00%)	0 (0.00%)

Source: The WHO e-Atlas of disaster risk for the European Region - Volume 1. Exposure to natural hazards (version 2.0) World Health Organization 2010

In Figure 10-13, the area of Cyprus which is exposed to heat waves as well as the heat wave hazard (temperature) is presented.



10 year return period

Figure 10-13: Heat Wave Hazard Distribution Map (2, 5 and 10 year return period)

Source: WHO (http://www.who-eatlas.org/europe/countries/cyprus/cyprus-hazard.html)

According to Figure 4-2, the biggest part of Cyprus is exposed to medium heat wave hazard (32-41^{o}C), while the mountain areas are exposed to low heat wave hazard (27-32^{o}C) for a 2-year return period, while as the return period increases, the area of mountains that is exposed to low heat wave hazard decreases.

Considering the above, the exposure of public health to heat waves is characterized as **moderate to high**.

10.4.1.2 Assessment of adaptive capacity

The public health response of Cyprus in heat waves is based at forecasting heat waves, issuing warnings and providing advices for self protection from heat waves, through the mass media (television, radio, newspapers, public web sites). In addition, during severe heat waves in Cyprus (as in summer 2003), the government in order to protect its citizens from adverse health effects, recommends a curfew between the high risk hours of the day. Furthermore, working regulations prohibit outdoor labour work when temperature exceeds 40 ^{o}C. However, people frequently ignore curfews out of negligence, with all the adverse effects that may follow.

The majority of houses and indoor public areas as well as private trade facilities in Cyprus, are fully air-conditioned. Furthermore, there are communal centers fully air-conditioned to accommodate people with no access to an air-conditioned environment during days of elevated temperatures. However, the protection of the population from heat waves is not always possible.

As presented in Section 10.2.2, the ability of the health care system of Cyprus to respond to heat related incidents is sufficient. However, it is the rapid nature of some heat-related health effects such as heat strokes that people do not make it to the hospital.

Considering the above mentioned indicators, the adaptive capacity of Cyprus' public health to heat waves is characterized as **limited to moderate**.

10.4.2 Floods/storms related deaths and injuries

10.4.2.1 Assessment of sensitivity and exposure

Sensitivity

The main population groups that are considered sensitive to deaths and injuries from floods and storms are (i) the elderly over 65 (13.3%) which cannot move easily and fast in case of a flooding event and (ii) infants and young children (16.1%) especially if they are not under the protection of adult (CYSTAT, 2011).

Taking into account the above, the sensitivity of Cyprus population to floods and storms is considered **limited to moderate**.

Exposure

The flood hazard distribution map of Cyprus (Figure 10-14) indicates that the risk ranges from high to very high levels at the regions close to Nicosia and Morphou while at the southern coastal areas Paphos, Limassol and Larnaca the risk is medium. In the rest area of Cyprus particularly in Troodos Mountains, where the population density is low, the risk is very low.

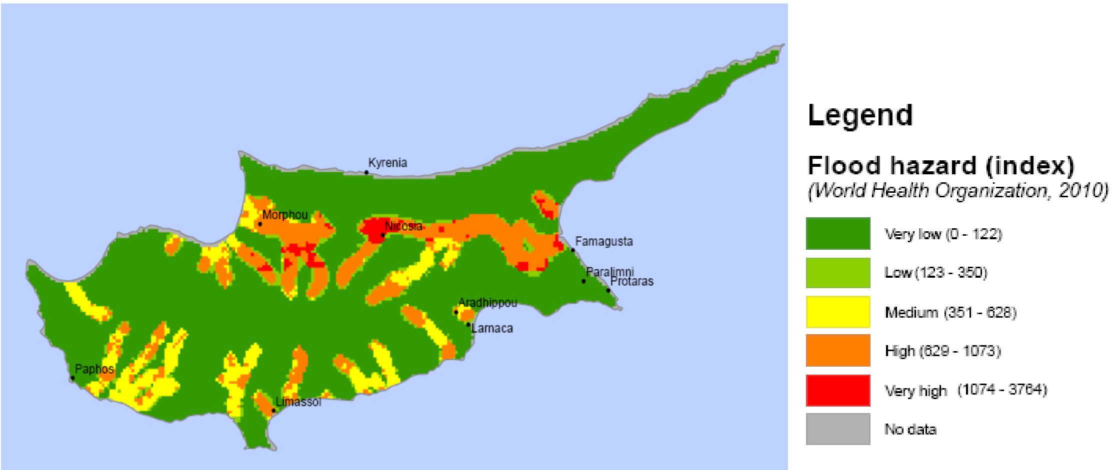


Figure 10-14: Flood hazard distribution map of Cyprus

Source: WHO, 2010. Available at: http://www.whoeatlas.org/europe/images/map/cyprus/cyp-flood.pdf

The total number and percentage of the population estimated to be exposed to floods in Cyprus by level of hazard are presented in the following table.

Table 10-6: Total number and percentage of the population exposed to floods by level of intensity in Cyprus

Hazard	Hazard intensity levels and number and percentage of people exposed					
	Very high No. exposed (%)	High No. exposed (%)	Medium No. exposed (%)	Low No. exposed (%)	Very low No. exposed (%)	No data No. exposed (%)
Flood	185,389 (21.07%)	183,380 (20.85%)	27,752 (3.15%)	77,684 (8.83%)	378,452 (43.02%)	27,066 (3.08%)

Source: The WHO e-Atlas of disaster risk for the European Region - Volume 1. Exposure to natural hazards (version 2.0)

According to the Table 10-6, 52% of people is estimated to be exposed to low and very low intensity levels of floods, while 42% is estimated to be exposed to high and very high flood hazard intensity levels.

The following figure illustrates the level of severity that recorded flooding events in Cyprus had for public health during the period 1859-2011, according to historical records collected by the Water Development Department of MANRE (2011).

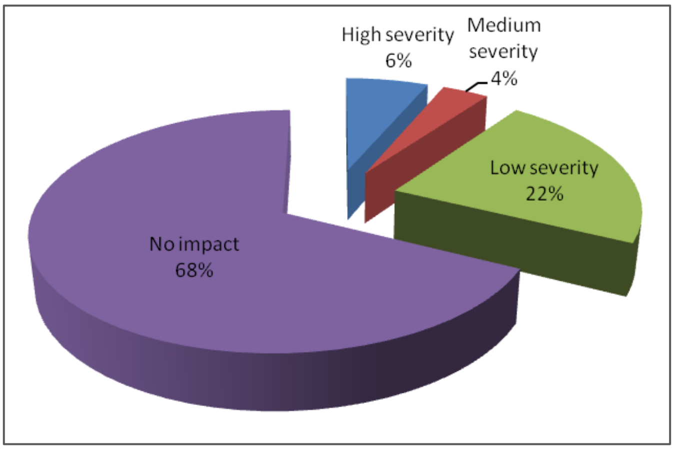


Figure 10-15: Impact of flooding events on public health (1859-2011)

Source: WDD, 2011

As shown in Figure 10-15, 6% of the recorded flooding events were characterized as of high severity for public health, 4% and 22% of medium and low severity respectively, while the majority of flooding events did not have any impact on human health.

Considering the above, the exposure of public health in Cyprus to floods can be characterized as **moderate**.

10.4.2.2 Assessment of adaptive capacity

For the protection of people during a severe flooding event, the civil preparedness and defense service of Cyprus is in place. In addition, the health care system of Cyprus cherishes injured people.

To prevent the occurrence of flooding events in Cyprus, a separate drainage system is being developed and expanded the last two decades in order to collect stormwater. So far, the drainage network in the majority of the big urban centres of Cyprus has been completed. Furthermore, the Sewerage Board of Limassol-Amathus in cooperation with the five municipalities of the Greater Limassol area as well as the wider area of Paphos began the implementation of Sustainable Urban Drainage Systems (SUDS). SUDS are actually a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water.

In Cyprus, 19 areas have been identified as areas for which Potential Significant Flood Risks exist or might be considered likely to occur, in accordance with the EU Directive on flood risk assessment and management. Furthermore, the directive states that Flood Risk Management Plans must be prepared by the end of 2015. It is expected that through the implementation of the Flood Risk Management Plans and the associated flood protection works, public health will be substantially safeguarded by the adverse effects of floods.

Until the implementation and the completion of the aforementioned flood protection works, the adaptive capacity of Cyprus public health to floods is characterized as **limited to moderate.**

10.4.3 Landslide-related deaths and injuries

10.4.3.1 Assessment of sensitivity and exposure

Sensitivity

The main population groups that are considered sensitive to deaths and injuries from landslides are (i) the elderly over 65 (13.3%) which cannot move easily and fast in case of a flooding event and (ii) infants and young children (16.1%) especially if they are not under the protection of adult (CYSTAT, 2011).

Taking into account the above, the sensitivity of Cyprus population to landslides is considered **limited to moderate**.

Exposure

According to the landslide hazard map produced by the World Health Organization (Figure 10-16), Cyprus population is not at risk from landslides, as in the greatest area of Cyprus the landslide hazard ranges from very low to low levels while only in the northern Turkish occupied part of Cyprus close to Kyrenia the hazard is medium.

Figure 10-16: Landslide Hazard Distribution Map of Cyprus

Source: WHO, 2010. Available at: http://www.who-eatlas.org/europe/images/map/cyprus/cyp-landslides.pdf

As shown in Table 10-7, the majority of the population in Cyprus (~97%) is exposed to low and very low landslide hazard, while only 0.01% is exposed to high landslide hazard.

Table 10-7: Total number and percentage of the population exposed to landslides by level of intensity for Cyprus

Hazard	Hazard intensity levels and number and percentage of people exposed					
	Very high (5)	**High (4)**	**Medium (3)**	**Low (2)**	**Very low (0-1)**	**No data**
Landslide	0 (0.00%)	121 (0.01%)	182 (0.02%)	517,801 (58.86%)	332,476 (37.79%)	29,143 (3.31%)

Source: The WHO e-Atlas of disaster risk for the European Region - Volume 1. Exposure to natural hazards (version 2.0)

Therefore, the exposure of public health in Cyprus to landslide related deaths and injuries is considered **limited**.

10.4.3.2 Assessment of adaptive capacity

For the protection of people from landslides, the civil preparedness and defense force of Cyprus is in place. In addition, the health care system of Cyprus cherishes injured people. For the protection of communities living in landslide prone areas from future landslides, entire settlements have been relocated to safer places. In places where landslides have occurred, technical structures were built in order to prevent human accidents and damages to infrastructure.

Currently, there is an ongoing effort to create a database with the recorded landslides. Furthermore, the Geological Survey Department of Cyprus has undertaken a research project entitled 'Study of landslides in areas of Paphos District', the main purpose of which is to promote a more secure urban development. However no action plans have been developed to date for the prevention and management of landslides.

Considering the magnitude of the impact of landslides on public health which is estimated as limited to moderate, the developed adaptive capacity to cope with the impact, is characterized as **moderate**.

10.4.4 Fire-related deaths and injuries

10.4.4.1 Assessment of sensitivity and exposure

Sensitivity

The main population group that is sensitive to fire-related deaths and injuries are the elderly aged over 65 (13.3%, see Table 10-2) which cannot move easily and fast in case of a fire event. In addition, infants and young children (16.1%, see Table 10-2) which have not yet developed the sense of risk and of self-protection, are sensitive, since if not under the protection of adults they will be trapped in the fire. As a result, the sensitivity of the population in Cyprus to fire related deaths and injuries is considered as **moderate**.

Exposure

Given that there are no data on the number of people killed or injured during fire events in Cyprus, the exposure will be estimated based on the fire risk areas (Figure 10-17) in conjunction with the population density in these areas (Figure 10-18).

The areas exposed to "very high" fire risk in Cyprus are mainly the forest areas of Troodos' mountains and the northern Pentadactylos range where the population density is very low. Moreover, in certain southern coastal areas close to Paphos and Limassol where the fire risk ranges from "moderate" to "low", where the population density is low (1-25 persons/km^2).

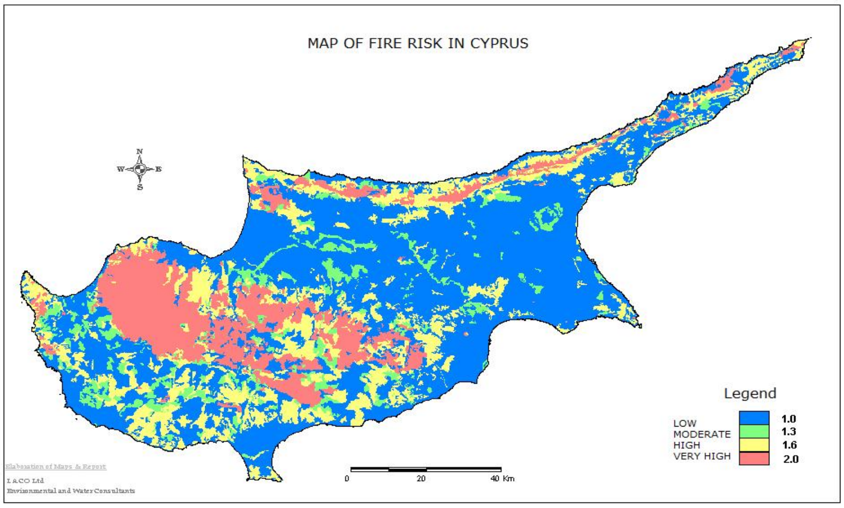


Figure 10-17: Map of fire risk in Cyprus

Source: Environmentally Sensitive Areas to Desertification Map, I.A.CO Ltd Environmental and Water Consultants

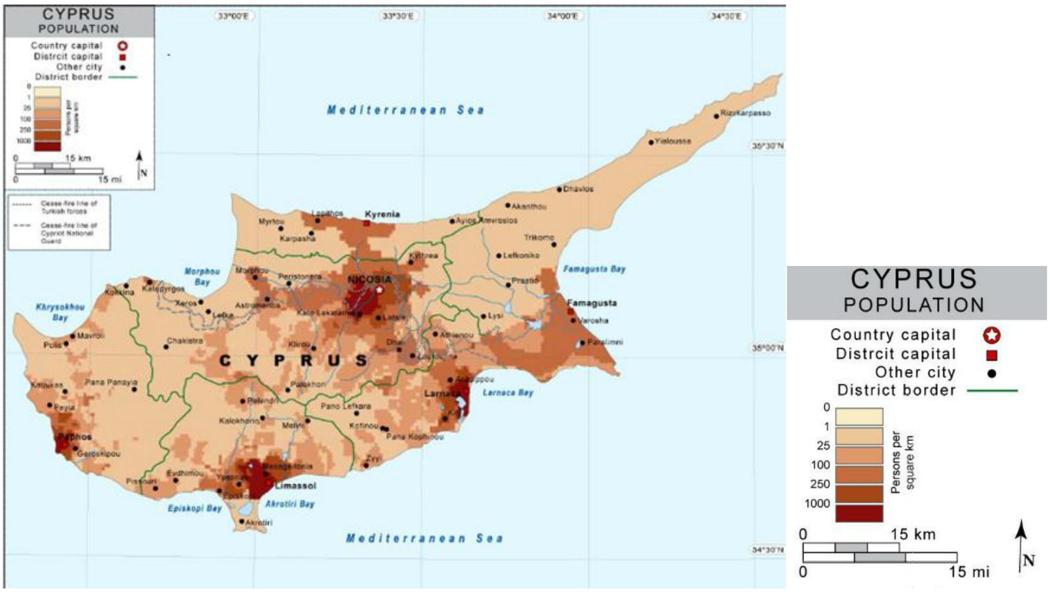


Figure 10-18: Population density in Cyprus

Source**:** http://www.bestcountryreports.com/Population_Map_Cyprus.php

Considering the above, the exposure of the population in Cyprus to fire-related deaths and injuries is characterized as **limited to moderate**.

10.4.4.2 Assessment of adaptive capacity

In Cyprus, even though there are no specific adaptive measures for fires with regard to public health, the fire brigade, the civil preparedness and defense service as well as the health care system are in place in order to protect the population from fires.

Several measures are taken by the Forestry Department of Cyprus aiming to eliminate forest fires including prevention, pre-suppression, detection and suppression measures. The measures that directly concern public health are: information campaigns on fire prevention and protection, fire danger mapping, installation of fire protection systems in areas where large numbers of people may concentrate.

Therefore, the adaptive capacity of Cyprus public health to fire-related deaths and injuries can be characterized as **moderate.**

10.4.5 Vector-borne and rodent-borne diseases

10.4.5.1 Assessment of sensitivity and exposure

Sensitivity

Incidents of vector-borne and rodent-borne diseases are more likely to be detected in population groups with lower socio-economic status and lower access to sanitation. Population groups characterized by high risk of poverty in Cyprus amounted to 16% of the total population in the period 2005-2008 (see Table 10-1). Access to an improved sanitation system (public waste water network, septic tanks) is important, especially in urban areas where the risk of contact of the population with waste water is more frequent. In Cyprus 100% of the population living in urban and rural areas have access to sanitation (Figure 10-19).

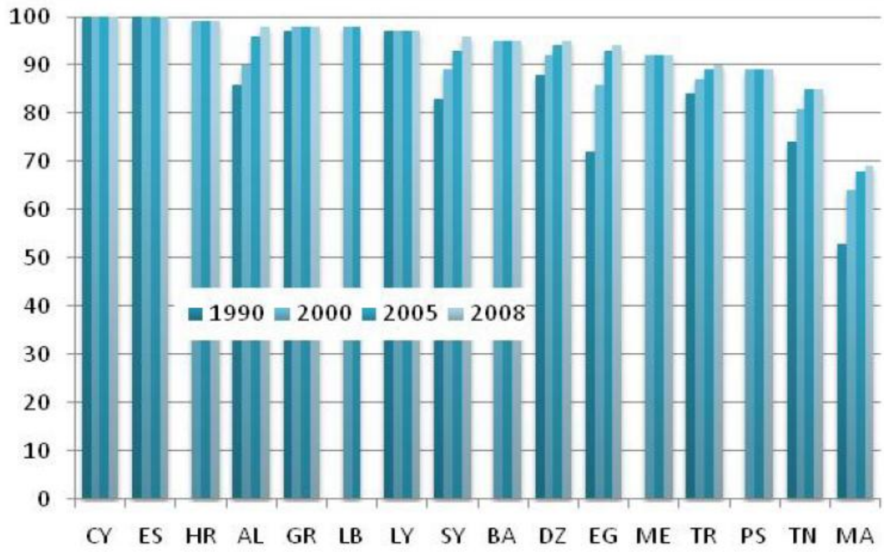


Figure 10-19: Share of population with access to an improved sanitation system, 1990 – 2006 (%)

Source: Plan Blue, 2011

Taking into consideration the above, it is estimated that the sensitivity of public health in Cyprus to vector-borne and rodent-borne diseases is **limited**.

<u>Exposure</u>

The exposure of public health to vector-borne and rodent-borne diseases is more possible during periods of increased temperatures and prolonged droughts as a result of the ideal conditions for the thriving of vector borne diseases (stagnation, contamination of small rivers). These conditions are a quite frequent phenomenon in Cyprus, especially during summers.

In 2007, the Cyprus Public Health Service has released a report on the mosquito surveillance program of the Republic of Cyprus conducted over the past 10 years. Twenty-three species belonging to 6 genera and 10 subgenera have been recorded to date, including species documented from earlier surveys. As a result of this program, new mosquito species for Cyprus have been recorded, including Anopheles marteri, Culex theileri, Cx. impudicus, Culiseta subochrea, and Uranotaenia unguiculata (Cosmatos, 2009).

However, Cyprus presents the lowest rate for vector-borne diseases among other countries. According to data provided by the United Nations Environment Programme UNEP, there have been no recent deaths in Cyprus due to malaria, although malaria did plague Cyprus for many years in the past. It was in 1946 when a well organized Anopheles eradication campaign started, while the official mosquito eradication completed on January 1950 (Cosmatos, 2009).

Considering the above, the exposure of public health in Cyprus to vector-borne and rodent-borne diseases is characterized as **limited to moderate**.

10.4.5.2 Assessment of adaptive capacity

Monitoring and identification of mosquito species is an important component of the Public Health Service's commitment to protecting the health of residents and preventing the spread of vector-borne diseases (Cosmatos, 2009).

The measures currently available to control vector-and rodent-borne diseases are disease-specific and can be broadly classified into diagnosis and treatment, vaccination, vector control, reservoir host control (spaying stagnant waters especially during summer), information and health education as well as disease surveillance and monitoring. In addition, the fact that 100% of the population in Cyprus has access to sanitation systems enhances Cyprus adaptive capacity.

Considering the above, the adaptive capacity of Cyprus public health to vector-borne and rodent-borne diseases can be characterized as **moderate**.

10.4.6 Water-borne and food-borne diseases

10.4.6.1 Assessment of sensitivity and exposure

Incidents of water-borne and food-borne diseases are more likely to be detected in population groups with lower socio-economic status, with lower access to sanitation and safe drinking water supply. Population groups characterized by high risk of poverty in Cyprus amounted to 16% of the total population in the period 2005-2008 (see Table 10-1). Access to an improved sanitation system (public waste water network, septic tanks) is important, especially in urban areas where the risk of contact of the population with waste water is more frequent. In Cyprus 100% of the population living in urban and rural areas have access to sanitation (see Figure 10-19). Provided that many waterborne diseases are associated either directly or indirectly, to the quantity and quality of the water supply, people with limited access to clean water and adequate sanitation facilities are the most vulnerable. In Cyprus 100% of the population has access to safe water both in rural and urban areas (100%) (Figure 10-20).

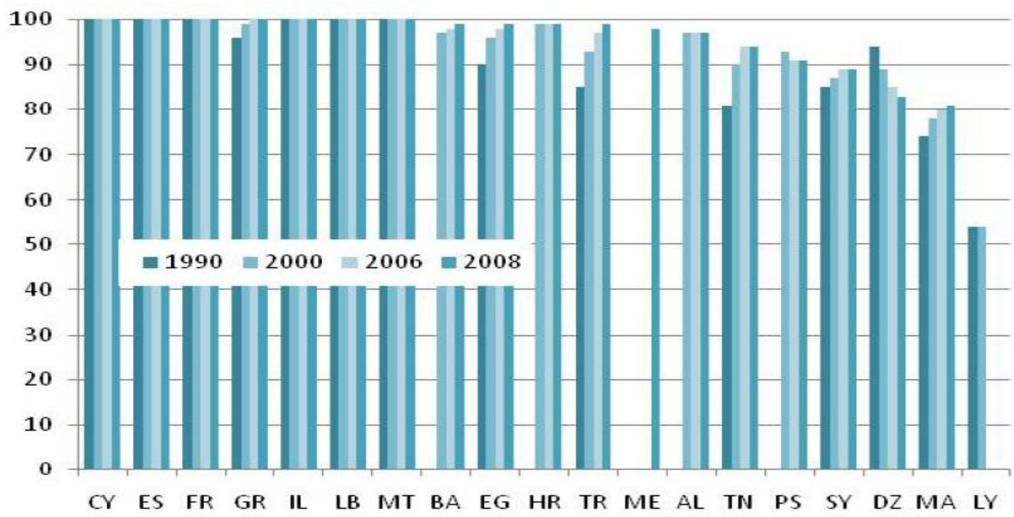


Figure 10-20: Share of population with access to an improved water source, 1990-2006 (%)

Source: Plan Blue, 2011

Taking into consideration the above, it is estimated that the sensitivity of public health in Cyprus to water-borne and food-borne diseases is **limited**.

Exposure

Twenty-six communicable diseases including cholera, dysentry, typhoid fever (all forms), infectious hepatitis A and food poisoning are notified in Cyprus under the Quarantine Law (WHO, 2003). An overview of the food-borne diseases notified in Cyprus during the period 1993 to 2000 is given in Figure 10-21.

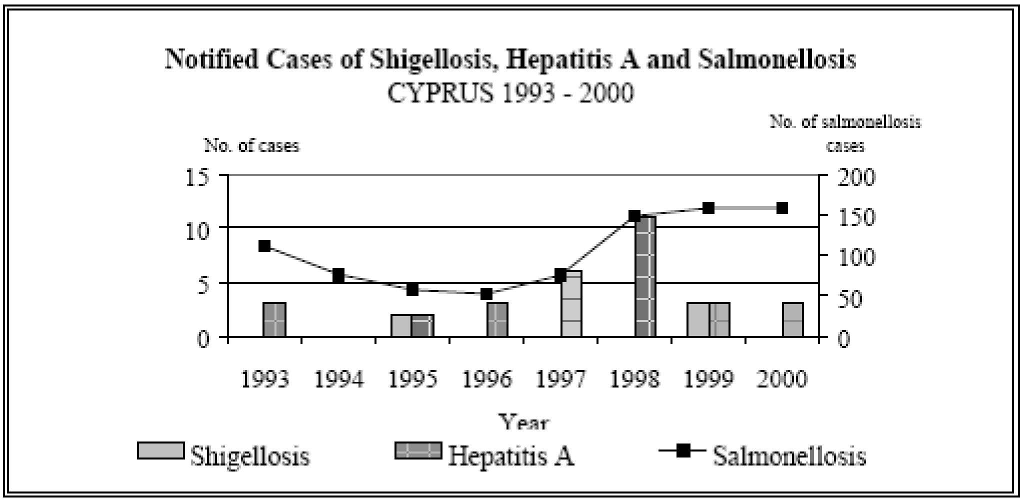


Figure 10-21: Notified cases of infectious diseases

Source: WHO, 2003

Under the statutory notification system, a total of 168 and 164 cases of infectious diseases were notified in Cyprus in 1999 and 2000 respectively. More than 90% of the notified cases were salmonellosis.

Table 10-8: Number of notified cases and incidence rates of infectious diseases for the period 1999-2000

Disease	1999		2000	
	Number of notified cases	Incidence rate	Number of notified cases	Incidence rate
Salmonellosis	158	23.62	158	23.54
Staphylococcosis	0	0.00	0	0.00
Shigellosis	3	0.45	0	0.00
Cholera	0	0.00	0	0.00
Brucellosis	0	0.00	1	0.15
Hepatitis A	3	0.45	3	0.45
Echinononnosis	4	0.60	2	0.30

Source: WHO, 2003

Furthermore, taking into consideration the following facts:

- The estimated number of "healthy" life years lost (DALYs) attributable to water, sanitation and hygiene for 16 Member States of the EU27, shows that Cyprus is in the first place (reference year 2002)(see Figure 10-6);
- The recorded incidents of salmonellosis in Cyprus for the period 1984-2007 present a general increasing trend, although they remain quite below the average respective values in the EU (see Figure 10-7);
- The incidents of Hepatitis A in Cyprus are quite low (less than 1 incident/100,000 capita per year) for the period 1980-2007 while the respective value for the EU was significantly higher until recently when it declined (Figure 10-8),

the exposure level of population to water and food-borne diseases can be characterized as **limited to moderate**.

10.4.6.2 Assessment of adaptive capacity

The food-borne Disease Surveillance System in Cyprus (1999-2000) is illustrated in Figure 10-22. The system involves the collaboration between physicians and health care services. Notification of food-borne diseases by the attending physician is usually followed by laboratory confirmation of the infection. Because of this, it is not always possible to secure prompt action which would allow for the proper investigation and control of the disease.

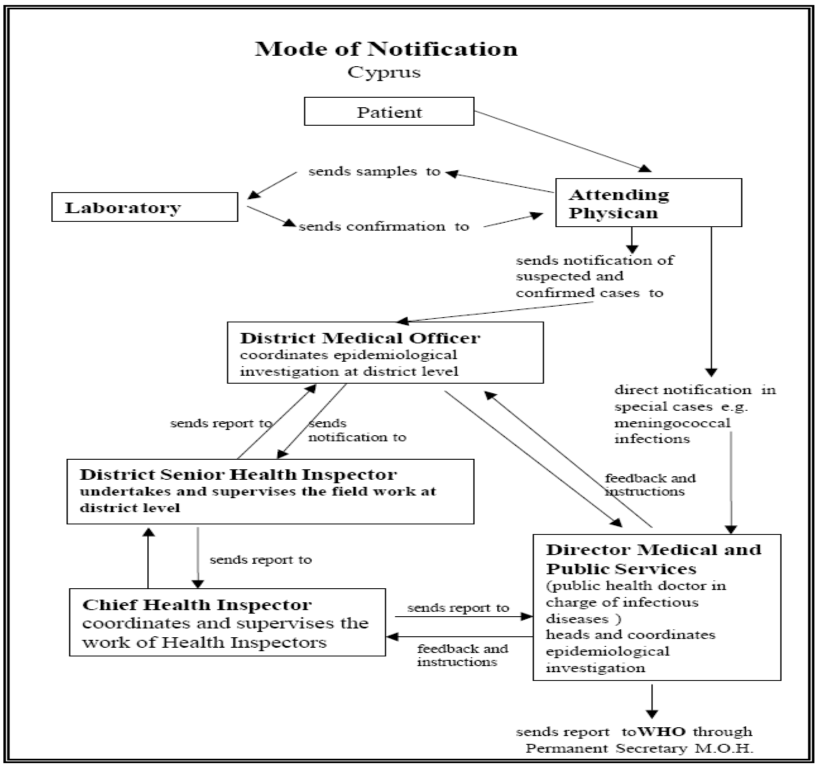


Figure 10-22: Cyprus notification mode of food-borne diseases

Source: WHO, 2003

The Ministry of Health, the Ministry of Agriculture, Natural Resources and Environment and the Ministry of Labour and Social Insurance jointly are responsible for environmental health. Their responsibilities include inter alia the monitoring of pollution levels and the monitoring of the environmental pollution level of drinking water supplies from pesticides and other micro pollutants. The General Laboratory of the Ministry of Health is responsible for performing controls on food and water samples for ensuring quality and safety. In addition, the National Committee for Nutrition which was established by the Ministry of Health in 1992 is responsible inter alia for monitoring compliance with state legislation on food safety and quality. In line with this a comprehensive list of controls is performed on food and water samples.

Finally, taking into consideration that 100% of the population in Cyprus has access to sanitation, it is considered that the adaptive capacity of Cyprus to water-borne and food-borne diseases is **moderate to high**.

10.4.7 Climate-related effects upon nutrition

10.4.7.1 Assessment of sensitivity and exposure

Sensitivity

Incidents of malnutrition are more likely to be detected in population groups with lower socio-economic status as well as to infants and young children. The population groups characterized by high risk of poverty in Cyprus amounted to 16% of the total population in the period 2005-2008 (see Table 10-1). The percentage of infants and young children amounts to 16.2% of the total population (see Table 10-2).
Consequently, it is assumed that the sensitivity of public health in Cyprus to climate-related effects upon nutrition is **moderate**.

Exposure

During drought years in Cyprus, the agricultural sector is the first to receive water cuts. As a consequence, significant reductions in farmers' yields are recorded and especially in seasonal crops such as vegetables and potatoes.

In absence of data related to the quantities of damaged crops in Cyprus due to extreme climatic phenomena and their impact upon nutrition, the amounts of compensation provided to farmers for loss in their yields caused by frosts, droughts, heat waves, wind storms, hail and floods were used as indicators of exposure assuming that the amount of compensation provided is directly related to the crop areas destructed. As it can be seen for Figure 10-9 and Figure 10-10, the main climatic factors affecting agricultural production and subsequently food availability are frosts and droughts.

The magnitude of the exposure on public health is however associated with the degree of dependence of the population on its agricultural production for satisfying its nutritional requirements. In Cyprus, nutrition is based on both agriculture and livestock national production but also on imports, thus climate-related effects upon nutrition are considered to have **limited** exposure to public health.

10.4.7.2 Assessment of adaptive capacity

The measures to protect public health from undernutrition are associated with the measures to secure water availability for irrigation in periods of droughts (e.g. use of recycled water, increase water storage capacity, satisfaction of drinking water supply by desalination plants etc.) and the measures for the protection of crops from extreme climatic events (e.g. installation of hedgerows, green houses etc). Last but not least, the economic ability of Cyprus to secure food availability even when national productivity is reduced through imports of agricultural, meat and dairy products substantially enhances the adaptive capacity of Cyprus. It must also be noted that, the National Committee for Nutrition, is responsible inter alia for safeguarding the production and distribution of food products.

Consequently, the adaptive capacity of Cyprus public health to the climate-related effects upon nutrition can be characterized as **high.**

10.4.8 Air pollution-related diseases

10.4.8.1 Assessment of sensitivity and exposure

Sensitivity

Certain groups are potentially more vulnerable than others to air pollution. These include children, pregnant women, people over 65 years of age, and persons suffering from cardiovascular and respiratory diseases (e.g. asthma). Depending on their age, children may be more vulnerable than adults while elderly people may be particularly vulnerable to air pollution because the ability to eliminate chemicals from the body decreases with age. However, they may also be less sensitive to some effects such as irritation of the eyes and nose. Persons suffering from cardiovascular diseases are more vulnerable to particles and those suffering from respiratory diseases such as asthma are more vulnerable to several air pollutants. The data available on these population groups in Cyprus, show that the percentage of children under 14 years old is 16.1% of the total population in Cyprus (see Table 10-2), the percentage of the elderly is 13.3% (see Table 10-2) and that the percentage of admissions in hospitals with respiratory diseases diagnosed is approximately 8% of the total admissions while for the other population groups there are no sufficient data. Considering the above, it is estimated that a percentage above 30% is considered vulnerable to air population. Therefore, the sensitivity of Cyprus public health to air pollution is considered **moderate**.

Exposure

The ground-level ozone in Cyprus constitutes an overall transboundary problem. However, in the cities the ozone concentrations are lower than in the background because of the depletion by the primary emitted pollutants there. According to Figure 10-23, the ozone level in Cyprus shows high values in high elevated background areas like in Troodos Mountains while in the urban cities is low. Considering the fact that population density in the Troodos area is low, the exposure of population to ozone is limited.

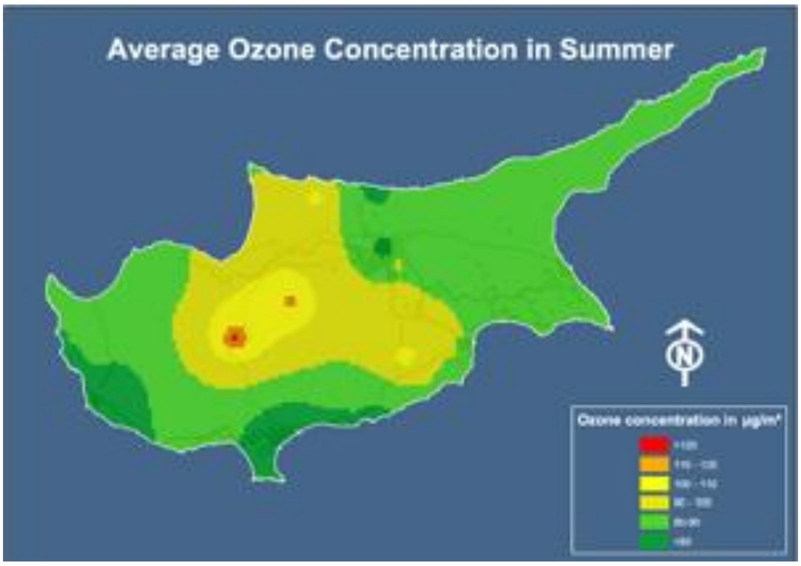


Figure 10-23: Average Ozone Concentration in Cyprus

Source: Department of Labour Inspection, Cyprus

According the results of "Preliminary Assessment of Ambient Air Quality and Drawing Up of Zones of Pollution in Cyprus" that was carried out in accordance with the EU Framework Directive 96/62/EC on ambient air quality assessment and management, the particulate matter (PM10) in Cyprus primarily originate from Sahara dust events and anthropogenic activities such as traffic and secondarily industrial activities. As it can be seen from Figure 10-24, the higher values of PM10 have been recorded in the main urban centers (reaching the EU limit values), where approximately 70% of the population leaves.

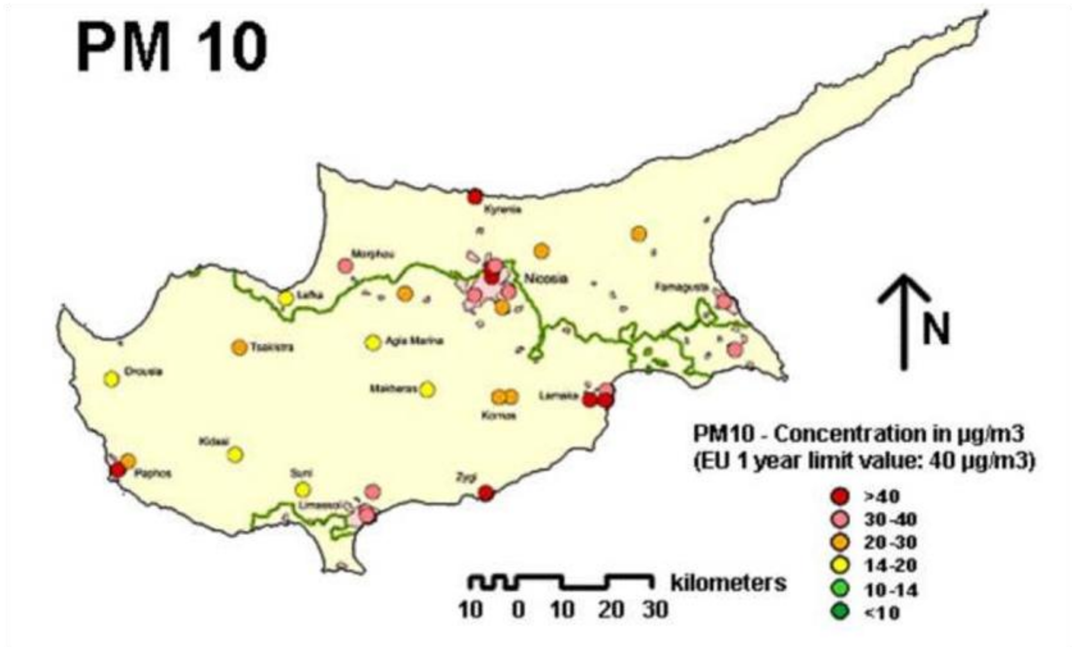


Figure 10-24: Annual PM10 concentrations in Cyprus including Sahara dust events

Source: Ministry of Labour and Social Insurance, 2007

As shown in Figure 10-25, the higher rates of nitrogen dioxide (30-40 and 40-54 µg/m^3 NO_2) are observed mainly in the urban areas and particularly in Nicosia, Limassol, Paphos and Larnaca, where approximately 70% of the population leaves.

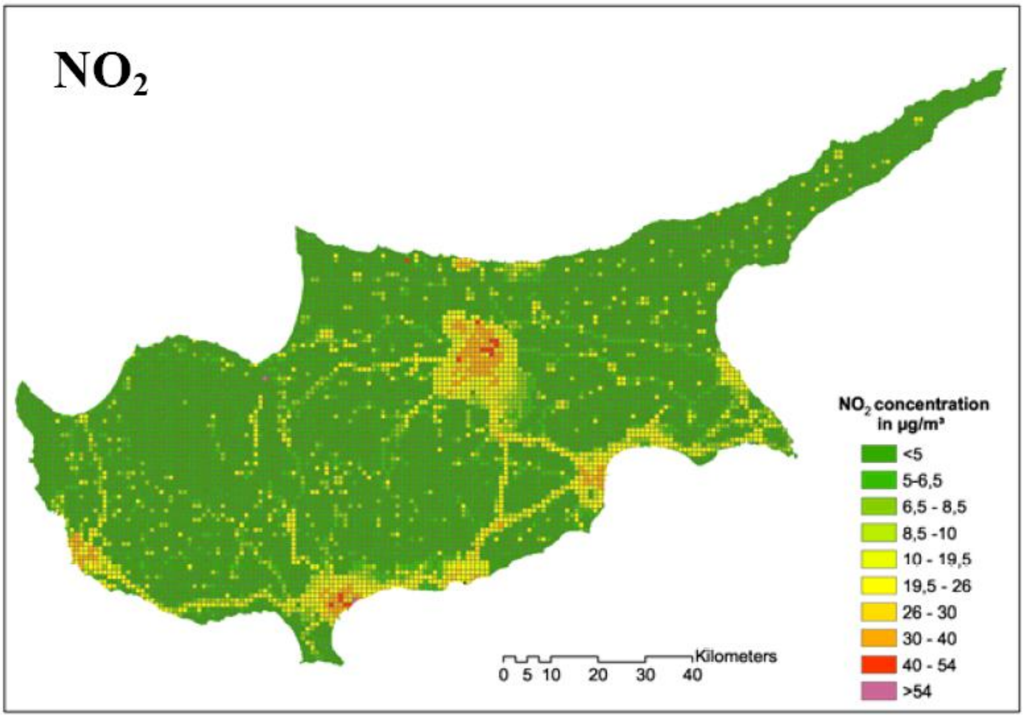


Figure 10-25: Spatial distribution of nitrogen dioxide (NO_2) as an annual average during the years 2003-2004

Source: Ministry of Labour and Social Insurance, 2007

An increase in summer humidity would drastically increase the biological disease potential in the air. According to the Meteorological Service of Cyprus relative humidity of the air is on average between 65% and 95% in winter and between 40% and 60% in summer. Additionally, pollutants from forest fires in Cyprus can effect air quality for thousands kilometers.

According to the environmental burden of disease by category of air-related diseases of Cyprus, the country rates for cardiovascular diseases, asthma and respiratory infections are presented at the following table.

Table10-9: Environmental burden of disease for air-related diseases in Cyprus

Disease group	World's lowest country rate	Country rate	World's highest country rate
Cardiovascular disease	1.4	3.6	14
Asthma	0.3	0.5	2.8
Respiratory infections	0.1	0.5	71

Source: WHO, 2009

Cyprus possesses low rates compared with world's rates (lowest and highest) while the rate of cardiovascular diseases is higher than those for asthma and respiratory diseases.

Considering the above, the exposure of the public health of Cyprus to atmospheric pollution is characterized as **moderate**.

10.4.8.2 Assessment of adaptive capacity

The measures for controlling air-pollution related diseases are mainly related to the provision of medical services by the health care system of Cyprus for facing such diseases as well as measures for the prevention of such diseases, with the mitigation of air pollution. In specific, the Department of Labour Inspection of the Ministry of Labour and Social Insurance of Cyprus, operates a national network of nine stations for monitoring air quality (Ministry of Labour and Social Insurance, 2007).

The measures for air pollution mitigation applied in Cyprus are:

- Enforcement of air quality EU directive
- National and regional plans for air quality improvement
- Action Plan for the support of public transportation in Cyprus

Consequently, the adaptive capacity of Cyprus to deal with air pollution can be characterized as **moderate**.

10.4.9 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of public health to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of public health against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for the public health sector in Cyprus are summarized in Table 10-10.

Table 10-10: Overall vulnerability assessment of public health in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Deaths and health problems related to heat waves and high temperatures	High (5)	Moderate to High (4)	Limited to moderate (2)	Moderate (3)
Deaths and injuries from floods/storms	Limited to Moderate (2)	Moderate(3)	Moderate (3)	None (-0.6)
Landslide-related deaths and injuries	Limited to Moderate (2)	Limited (1)	Moderate (3)	None (-1.6)
Fire-related deaths and injuries	Moderate (3)	Limited to Moderate (2)	Moderate (3)	None (-0.6)
Vector-borne and rodent-borne diseases	Limited (1)	Limited to Moderate (2)	Moderate (3)	None (-1.6)
Water-borne and food-borne diseases	Limited (1)	Limited to Moderate (2)	Moderate to High (4)	None (-2.6)
Climate-related effects upon nutrition	Moderate (3)	Limited (1)	High (5)	None (-3.3)
Air pollution-related diseases	Moderate (3)	Moderate (3)	Moderate (3)	None (0)

As it can be seen from the table above, the public health of Cyprus is not considered vulnerable to climate changes mainly due to the fact that it is characterized by a good adaptive capacity. The only vulnerability that was identified through the present study, is related to the deaths and health problems related to heat waves and high temperatures considering that heat waves are quite frequent during summer in Cyprus and that a significant percentage of the population in Cyprus is partiqularly sensitive to heatwaves (elderly people), while the adaptive capacity is not safisfactory enough given that the protection of the population from heat waves is not always possible.

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11 ENERGY

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Abbreviations and Acronyms

A/P	Airport
CDD	Cooling Degree Days
EEZ	Exclusive Economic Zone
HDD	Heating Degree Days
HFO	Heavy Fuel Oil
RES	Renewable Energy Sources
toe	tons of oil equivalent
tcf	Trillion cubic feet
TSO	Transmission System Operator

11.1 Climate change and energy

Cyprus is an island situated in the north-eastern part of the Mediterranean Sea. It constitutes an isolated energy system, the energy requirements of which are covered mostly by oil imports, making Cyprus a highly energy dependent island (Koroneos, 2005; Zachariadis 2010). Until recently, renewable energy was considered to be as the sole indigenous form of energy. However, recent studies have revealed that Cyprus has significant amount of fossil fuel resources in its Exclusive Economic Zone (EEZ) and in specific the initial evaluation work of Noble Energy Ltd indicates an estimated gross resource range of 5 to 8 trillion cubic feet (Tcf) of natural gas, with a gross mean of 7 Tcf (see Section 11.4.3.2). This is expected to change the energy mix profile and consequently to improve the energy security of the island.

On a worldwide basis, it is expected that the energy sector will experience different impacts due to climate change, including change of the heating/cooling degree days over year[28], reduction of the overall efficiency of the power stations associated with the increase in temperature of the cooling medium used in the energy production process, reduction in hydropower production etc.

According to EEA (see also Figure 11-2) the Mediterranean basin has already been subjected to decreased precipitation something that is going to exacerbate as the climate change continues to persist and intensify. The decreased precipitation and stream flows will lead apart from low water availability, to decreased energy yield (regarding hydroelectricity). However, hydropower is not used in Cyprus and is not projected to be introduced to the energy mix of the island in the coming years, due to limited water resources and intermittent river flows. These impacts are discussed in Section 11.3.

Finally, in order to allow these impacts to be assessed in terms of viability, vulnerability and adaptive capacity (see Section 11.4), it is crucial to take into consideration the energy consumption patterns and their trends. These critical issues are discussed in the following chapter (Section 11.2) providing a comprehensive outlook of the current situation regarding the energy sector of Cyprus.

[28] The change in heating, cooling degree days is attributed to temperature increase. For the case of Cyprus the observed temperature increase between 1892 and 2007 is presented in Figure 11-1, while the reader can find further information regarding the observed changes in the climate of Cyprus in the CYPADAPT website (Deliverable 1.1: “Report on the observed changes and responses to climate change worldwide and in Cyprus”).

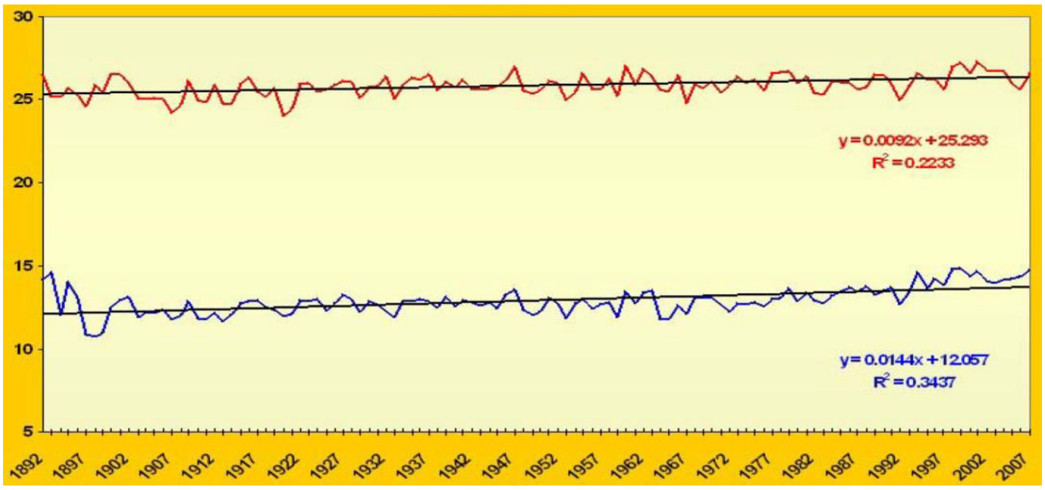


Figure 11-1: Maximum and minimum mean annual temperature time series in Nicosia.

Source: MANRE, 2010; http://www.moa.gov.cy

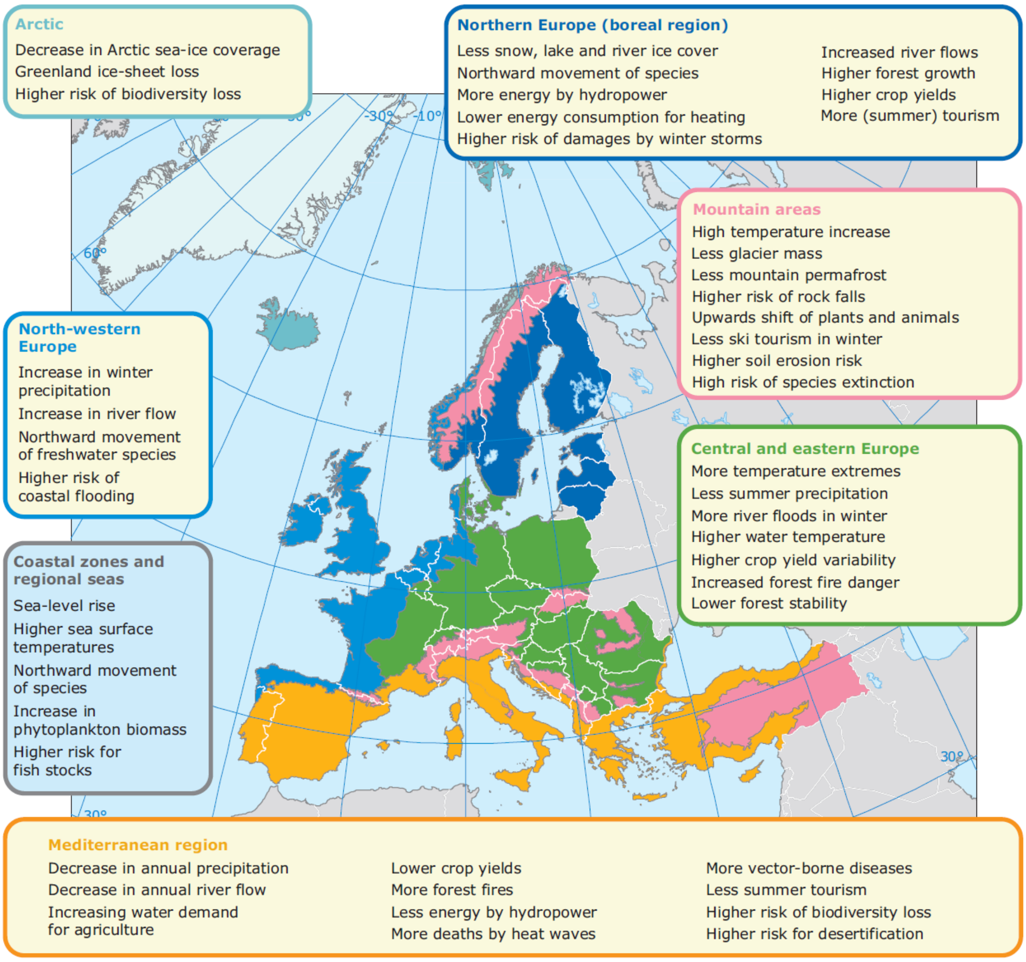


Figure 11-2: Impacts of climate change and effects on sectors in Europe.

Source: EEA, 2010

11.2 Baseline situation

11.2.1 Energy demand

In order to obtain an understanding of the energy profile of a country, a number of aspects should be examined, including but not limited to the following:

- Primary energy production;
- Gross inland energy consumption;
- Final energy consumption; and
- Electricity consumption.

These figures are examined and analyzed in the following sections. It must be noticed that electrical consumption was examined separately due to its particular significance for the energy sector.

11.2.1.1 Primary energy production

As defined by Eurostat, primary production comprises any kind of extraction of energy products from natural sources to a usable form (e.g coal mines, crude oil fields, hydro power plants, fabrication of biofuels etc.). It must be noticed however, that any transformation of energy from one form to another, such as electricity or heat generation in thermal power plants, or coke production in coke ovens, is not primary production (Eurostat, 2007).

In Cyprus, there are no indigenous energy resources, apart from renewable energy sources (RES). To this end, in order to meet the energy requirements of the island, the vast majority of fuels (>95%) is imported, making Cyprus a highly energy dependent island. The primary energy production of the year 2010 totaled 84,000 tons of oil equivalent (*toe*), while according to the latest data provided by the Energy Service of the Ministry of Commerce, Industry and Tourism[29]the breakdown by RES source category is as follows:

- Solar thermal: 61,070toe;
- PV systems (electricity): 550 toe;
- Biomass: 10,072 toe (6,215 toe thermal and 3,021 electricity);
- Biofuels (transport): 4,963 toe;
- Used oils (thermal): 5,466 toe;

[29] Contact person: Eleni Topouzi, Energy Service, Ministry of Commerce, Industry and Tourism of Cyprus

- Tyres and other fuels: 1,698 toe; and
- Geothermal: 753 toe

11.2.1.2 Gross inland energy consumption

As defined by Eurostat, the gross inland energy consumption[30] represents the quantity of energy necessary to satisfy inland consumption of the geographical entity under consideration and it covers: (a) consumption by the energy sector itself; (b) distribution and transformation losses; (c) final energy inland consumption by end users; and (d) 'statistical differences' (between primary energy consumption and final energy consumption).

The total gross inland energy consumption in Cyprus totaled 1,728 ktoe in 2010 (excluding road and air transport which represent an additional 989ktoe, resulting to a total of 2,717ktoe) (Eurostat[31]).

11.2.1.3 Final energy consumption

The final energy consumption[32] in Cyprus totaled 1,921 ktoe in 2010 and 1,926 in 2009 (including the transport sector). The major energy consumers along with their contribution to the final energy consumption are given below:

Table 11-1: Major energy consumers and their contribution to the final energy consumption of Cyprus

Energy consumers	2010[33]	2009 (EUROSTAT, 2011)
Transport	1,039 ktoe (54.1%)	1,019 ktoe (55.1%)
Households	295 ktoe (15.4%)	310 ktoe (16.8%)
Commerce & Services	235 ktoe (12.2%)	220 ktoe (11.9%)

[30] It can be calculated by the following formula: primary production + recovered products + net imports + variations of stocks – bunkers. Sometimes it is referred to as "**primary consumption**".

[31] It must be mentioned that it is possible that an error message may appear when opening the page. Should this happen use the following link http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_102a&lang=en and choose 'Final Energy Consumption' in the "INDIC NRG" field.

[32] **Final energy consumption** is the total energy consumed by end users, such as households, industry and agriculture and it excludes energy used by the energy sector, including energy transformation, transportation and deliveries.

[33] The information was obtained through communication with the Energy Service of the Ministry of Commerce, Industry and Tourism. Contact person: Eleni Topouzi.

Energy consumers	2010[33]	2009 (EUROSTAT, 2011)
Industry	236ktoe (12.3%)	260 ktoe (14.1%)
Agriculture & Fisheries	37 ktoe (2%)	37 ktoe (2%)

A more detailed picture of the final energy consumption and the energy sources balancing the energy requirements of each sector is presented in Figure 11-8.

Given that electrical supply plays a major role in the energy balance of an energy providing system, following a comprehensive analysis of the electrical system is provided.

11.2.1.4 Electrical demand

The total electrical requirements for the year 2010 were about 5,205,000 MWh, which represent a 28.71% increase compared to 2003 (7-year time period). A corresponding increase is expected by the year 2018, when a 33.14% (6,930,000 MWh) increase is estimated (EAC, 2010). The estimated maximum annual generation for years 2011 to 2016 is presented in Table 11-2.

The delivery of electricity to the different sectors of Cyprus for the year 2010 is presented in the following figure.

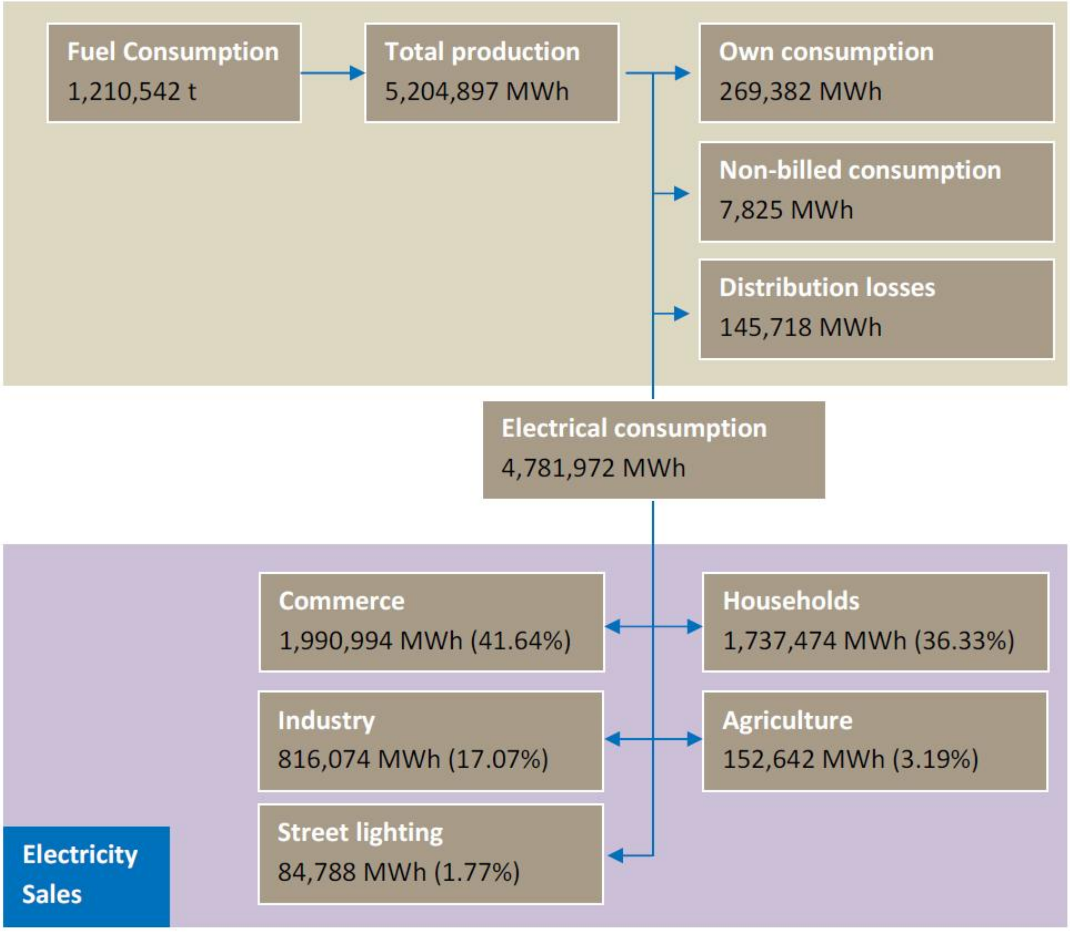


Figure 11-3: Share of different consumers in the electrical consumption in Cyprus. Source: EAC, 2011

Table 11-2: Maximum Generation Demand.

	2011	2012	2013	2014	2015	2016
Maximum Generation Demand (MW)	1,155	1,200	1,250	1,295	1,340	1,385

Source: TSO

11.2.2 Energy supply

As stated above, Cyprus has no indigenous energy resources (excluding renewable energy sources) and the energy requirements are covered to a great extent by oil imports.

These amounts of petroleum products are used:

- Directly, as for heating purposes;
- And indirectly, as for electricity production.

In regard with the indirect use of the fossil fuels for the production of electricity, different technologies are employed as discussed next.

11.2.2.1 Conventional electrical power supply

The electrical requirements of the island are provided by:

- three main power stations, namely: (a) Moni power station, (b) Vasilikos power station and (c) Dhekelia power station,
- self-producer installations (internal combustion units) whose total installed capacity reaches 21,6 MW (CERA, 2011).

Following a brief description of the public power stations is provided (EAC, 2011).

11.2.2.1.1 Moni Power Station

- **Location**: Southern coast of Cyprus
- **Total installed capacity**: 330 MW
  - 6x30 MW, steam turbine units burning heavy fuel oil. The last unit was commissioned in 1976, while the first two in 1966
  - 4x37.5 MW, oil fired gas turbines. The first two gas turbines were commissioned in 1992, while the other two in 1995
- **Thermal coefficient of efficiency**: (a) 24.56%, for the steam turbines and (b) 23.562%, for the gas turbines
- During 2010, Moni Power Station covered 4,98% (259 247 MWh) of the total electrical energy requirements

11.2.2.1.2 Vasilikos Power Station

- **Location**: Southern coast of Cyprus (25 km east of Limassol)
- **Total installed capacity**: 648 MW
  - 3x130 MW, steam turbine units burning heavy fuel oil (HFO)
  - 1x220 MW, Combined-Cycle Gas Turbines (CCGT)
  - 1x38 MW, diesel oil-fired gas turbine. This unit was commissioned in 1999 and mainly is used as a black start unit
- **Thermal coefficient of efficiency**: (a) 38.46%, for the steam turbines and (b) 22.73%, for the gas turbines, (c) 47.95% for the CCGT plant
- During 2010, Vasilikos power station covered 60.77% (3,162,958 MWh) of the total electrical energy requirements

11.2.2.1.3 Dhekelia Power Station

- **Location**: South east coast of Cyprus
- **Total installed capacity**: 460 MW
  - 6x60 MW, steam turbine units burning heavy fuel oil. The last unit was commissioned in 1993, while the first one in 1982
  - 2x50 MW, internal combustion units. The last unit was commissioned on the 1st of June, 2010.
- **Thermal coefficient of efficiency**: (a) 30.27%, for steam turbines and (b) 41.75%, for internal combustion engines
- During 2010, Dhekelias Power Station covered 34.25% (1,782,692 MWh) of the total electrical energy requirements

11.2.2.2 Renewable power supply

The share of renewable energy sources in the energy mix has increased quite recently in Cyprus under the Grant Scheme for the Promotion of Renewable Energy Sources (RES) and Energy Conservation. This policy measure received significant interest from the public, leading to an increased penetration of RES to the final energy consumption between 2005 and 2008, as illustrated in Figure 11-5.

During the last 2 years, Cyprus has experienced increased development in renewable energy sources, primarily from the use of solar and wind energy because of its relatively high wind and solar energy potential (see Figure 2-2). From a 4.1% share in total energy consumption in 2008, it reached 5.4% in 2010 (see Figure 2-4). By 2020, Cyprus has committed to the European Union that renewable energy will reach 13% (Kassinis, 2009; Kassinis, 2011).

The installed capacity of photovoltaic systems currently amounts to 9.3 MW while by 2015 it is expected to reach 14MW (see Section 11.3.1.1.3). Furthermore, in December 2010 two grant applications for solar thermal power plants were included in the Grant Schemes with a total capacity of 50 MW.

Additionally, the capacity of the wind farms already installed amounts to 133.5 MW (see Section 11.3.1.1.2) and is expected to reach 165MW in the coming years (Kassinis, 2011).

As regards the production of electricity from the use of biomass, there are currently 11 units running with a total installed power of 7.9 MW (see Section 11.3.1.1.4).

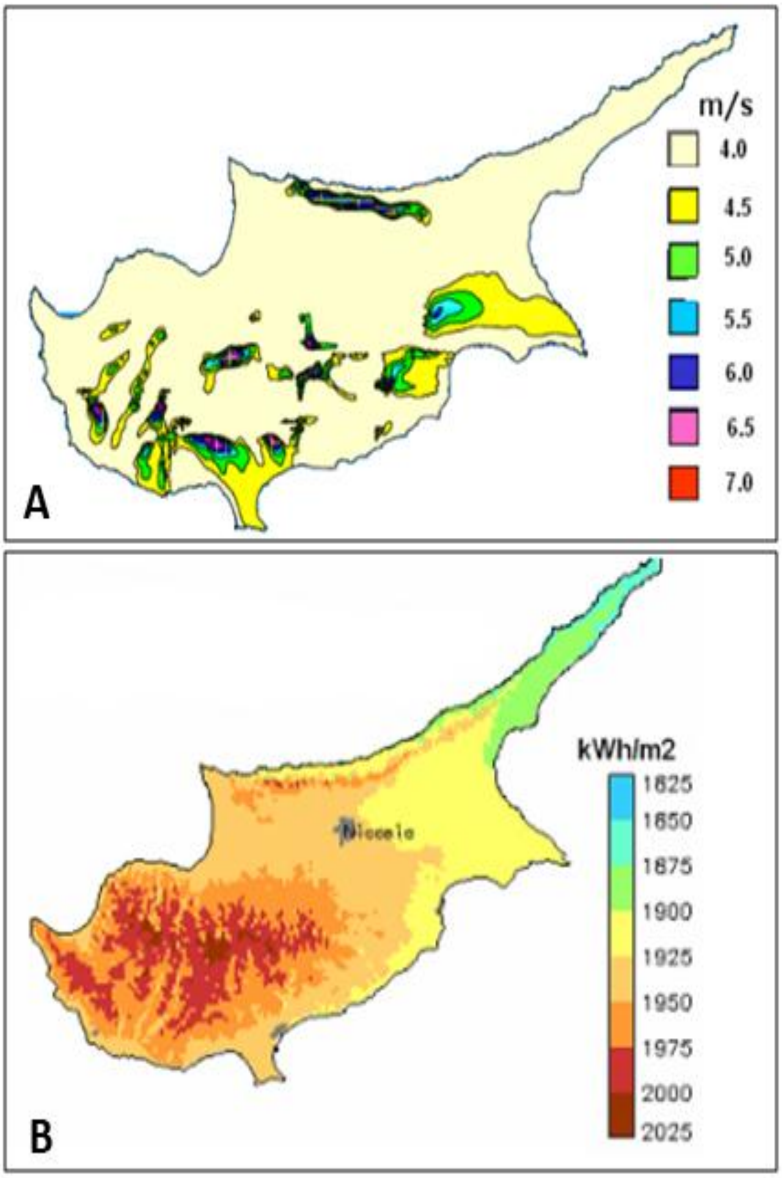
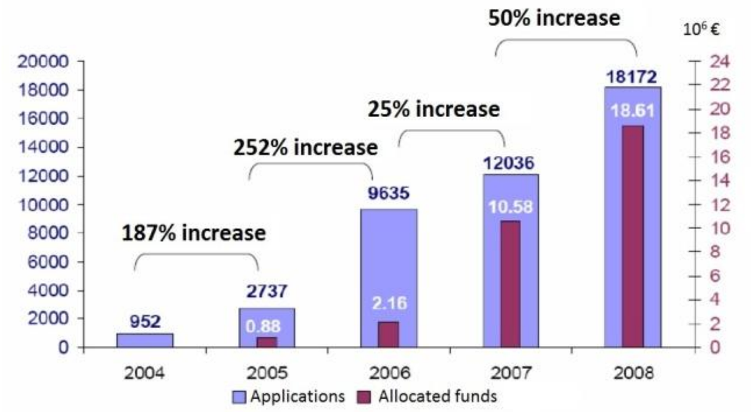
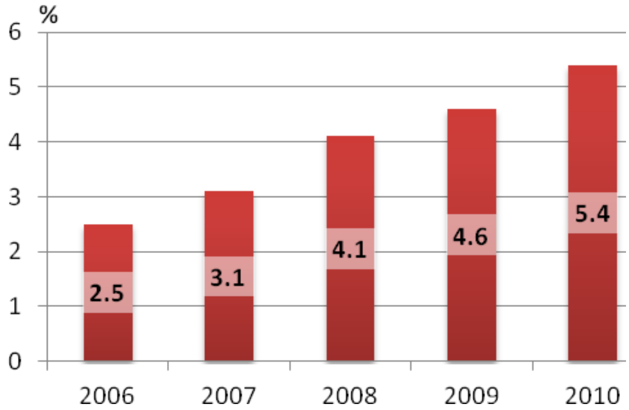


Figure 11-4: Spatial distribution of annual mean wind velocity in Cyprus in term of wind farm installation (A). Overall annual solar irradiation received bed a solar collector (B)

Source: Kassinis, 2009





Source: Eurostat

Figure 11-5: Penetration (share) of renewable energy sources in the final energy consumption

According to the Ministry of Agriculture, Natural Resources and Environment (MANRE, 2010) the contribution of the different energy resources to the final energy consumption, along with the breakdown of different renewable energy sources, is as presented in Figure 11-6.

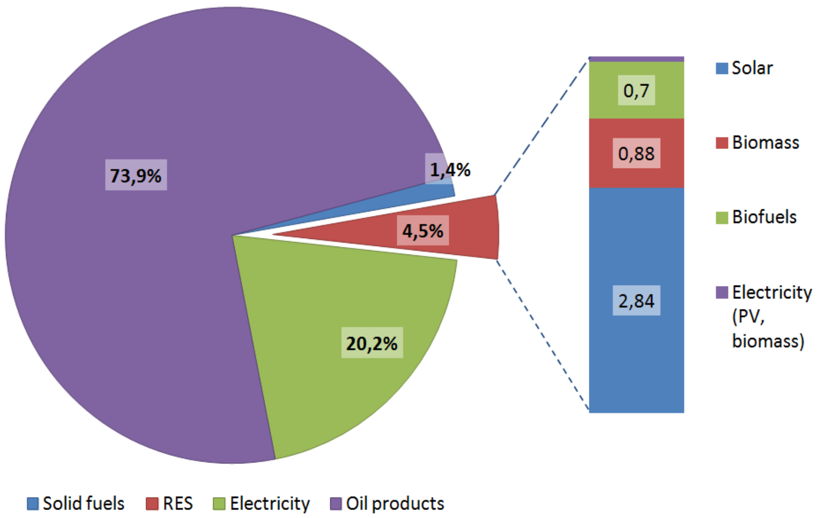
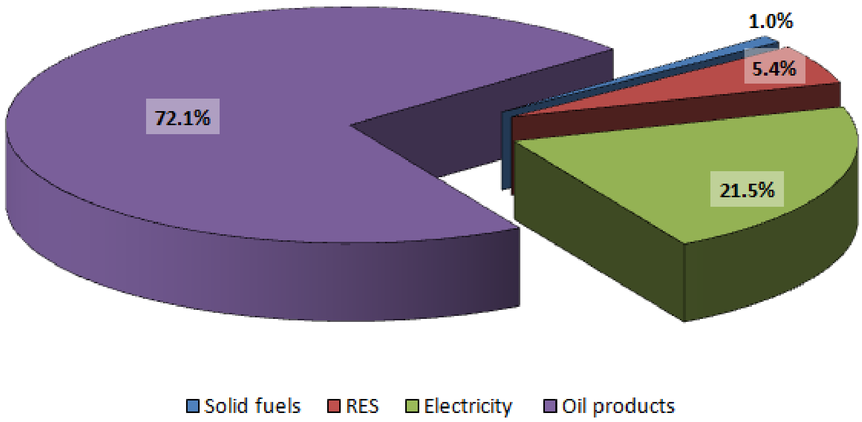


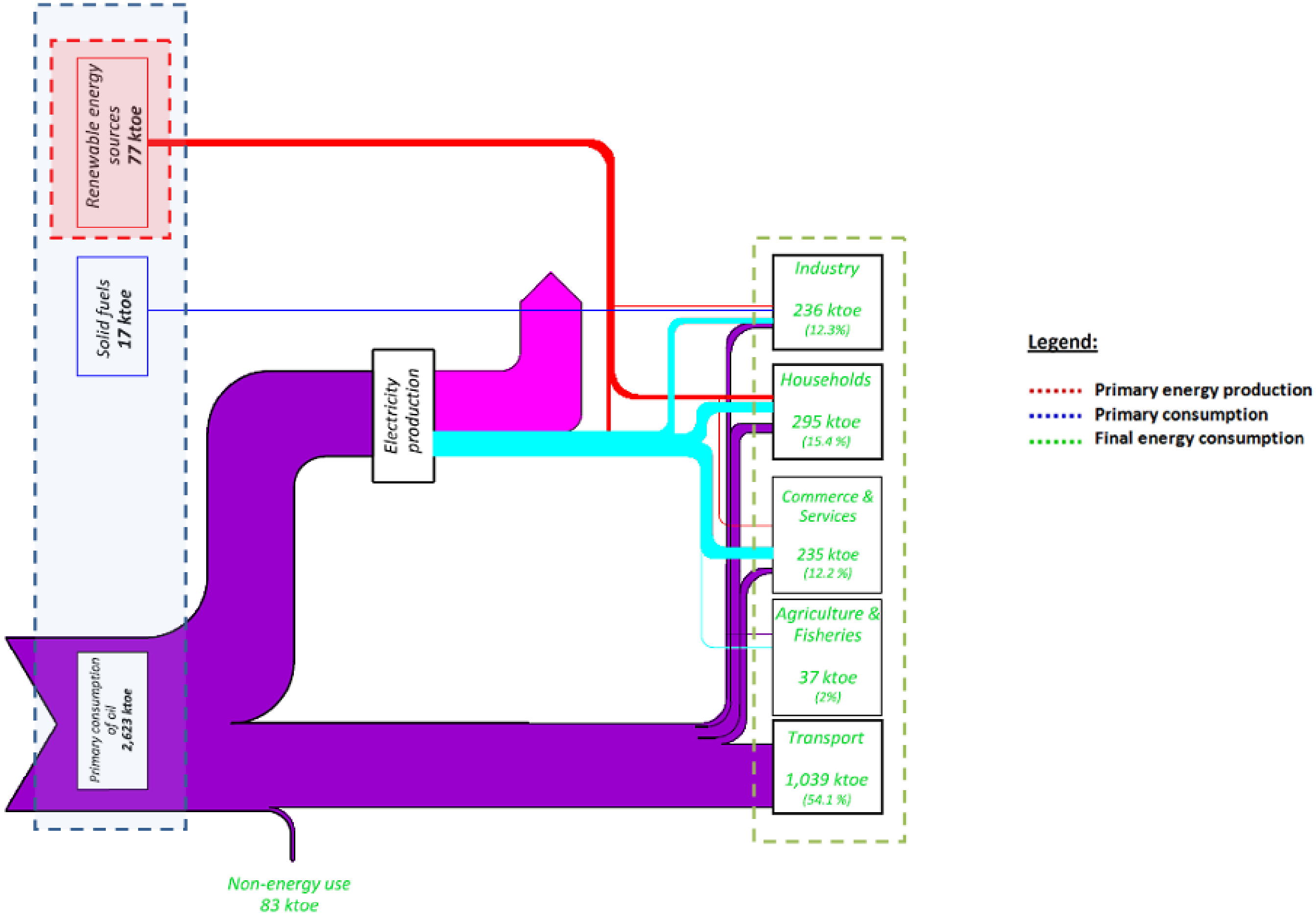
Figure 11-6: Contribution of renewable energy sources to the final energy consumption: breakdown by renewable sources (2008 data)

In the following figure the final energy consumption of Cyprus for the year 2010 is presented.



Source: Energy Service

Figure 11-7: Final energy consumption, 2010 data



Note: The primary energy consumption has been calculated on the basis of the formula described in Note 3, taking into account the following data provided by Eurostat: (a) Primary energy production: 84ktoe (out of which 77ktoe correspond to renewable energy), (b) recovered products: 1ktoe, (c) net imports: **2,924ktoe**, (d) variation of stocks: -111ktoe and (e) international bunkers: 182ktoe. To this end, the primary energy consumption for the year 2010 equals to: 84+1+2,924-111-182≈**2,717ktoe**

Source: Own production (NTUA working team)

Figure 11-8: Energy balance for the year 2010 in ktoe

11.3 Impact assessment

The climatic factors that are likely to induce impact on the energy sector are the following: (a) temperature and relative humidity; (b) precipitation; (c) wind and cloud cover; (d) extreme events. The most significant climatic factors, with regard to the impacts on the energy sector, are temperature and humidity increase and decreased precipitation[34].

Following, the potential climate-induced impacts on the energy sector in general, and for the case of Cyprus in particular are recorded. To this end, the approach of this work is to provide, where possible, quantified results in order to measure to the greatest extent the impact on each energy sub-sector.

In the context of the quantitative impact assessment the following indicators have been examined:

Table 11-3: Relationship between observed climate changes and impacts on the energy sector

Climate factor	Impacts on energy sector	Selected indicators
Induced by climate factors		
Increase in temperature and relative humidity	Increased cooling demand and decreased heating demand	• Heating degree days; • Cooling degree days; • Peak demand; • Energy intensity;
	Decreased thermal efficiency in thermal power plants	• Thermal coefficient of efficiency; • Energy capacity; • Installed capacity;
Precipitation	Change in Hydropower generation	• Share of electricity production from hydropower
	Change in Bio-power generation	• Share of electricity production from bio-power
Wind speed	Change in Wind power generation	• Share of electricity production from wind power
Cloud cover	Change in Solar power generation	• Share of electricity production from solar power
Induced by human pressures		
Oil prices		• Electricity production cost

The impacts of the energy sector are presented in detail next under the following categories:

- Renewable energy yield;
- Efficiency of thermal power plants; and
- Demand for electricity and cooling/ heating.

[34] Decreased precipitation is not considered as a significant climate factor, with regard to the impacts on the energy sector, as no hydro power plants exist in Cyprus (Section 11.2.2.2).

11.3.1 Renewable energy yield

As mentioned before, the primary energy production in Cyprus is limited only to renewable energy sources, while all fossil fuel resources used in the energy sector are imported from other countries.

According to the international bibliography, the renewable energy sources that are likely to be affected by climate change are the following: (a) hydropower; (b) wind power; (c) solar power and (d) bio-power (Kirkinen, 2005). The impacts observed on the aforementioned sources are discussed in the following sections.

11.3.1.1.1 Hydropower

The amount and seasonality of flow in most rivers can be affected by climate change, which in turn affects the power production by hydropower plants. According to the Environmental Energy Agency hydropower is expected to be significantly affected by climate-induced changes (see Figure 11-2). However, hydropower production will vary across regions as different precipitation patterns and rates of hydropower deployment have developed over time. More particularly, an increase in hydropower production by about 5% and more in northern Europe and a decrease by about 25 % or more in southern Europe is expected (EEA, 2010).

Situation in Cyprus

No hydropower plant exists until now in Cyprus, as the hydroelectric potential is very little to exploit. Only two applications of 330 kW have been submitted to CERA (CERA, 2011).

- **Current share of electricity production from hydropower**: 0%

Based on the above indicator, no impact is regarded on the hydropower production.

11.3.1.1.2 Wind power

The maximum power that can be produced by wind can be estimated by the following formula:

$$P_w = \frac{\pi}{8} \cdot D^2 \cdot \rho \cdot U^3 \qquad (11\text{-}1)$$

Where:

- D, the rotor diameter (m);
- ρ, the air density (kg/m^3); and
- U, air velocity (m/s).

The last two variables of the above equation (ρ, U) are dependent on climate changes. Moreover, it must be noted that even small changes in the air intensity can be translated into significant changes to the wind power produced, as the power is proportional to the third power of the wind velocity.

A climatic factor that can affect the wind power produced and is not included in equation 3.1, is the change in wind variability. For instance, if strong winds increase in frequency, wind power can be reduced, as there are specific cut-off wind velocities, depending on the type of the wind generator. As a result, even though in such a case the wind intensity rises, the produced power equals to zero.

Finally, it is reported that wind power production can be affected indirectly by other factors such as rain and icing (Kirkinen, 2005).

Situation in Cyprus

According to the most recent information (November 2011) provided by the Cyprus Energy Regulatory Authority, until August 2011 three wind parks have been installed with a total capacity of 133.5 MW (82 MW + 20MW+31.5 MW).

- **Electricity production (January 2011 – December 2011):** 114.3 GWh[35]
- **Total installed capacity (December 2011):** 133.5 MW
- **Current share of electricity production from wind power**: 2.2%[36]

As regards the production of electricity from the use of biomass, there are currently 12 units running with a total installed power of 8,6 MW. Moreover, three applications have been received and are currently being evaluated with a total capacity of 10MW. Furthermore, in December 2010 two grant applications for solar thermal power plants were included in the Grant Schemes with a total capacity of 25 MW (Kassinis, 2011).

Wind power was introduced to the Cypriot energy system in 2010. There are no available data for measuring the impact of climate change in wind power production. Relative research for monitoring the impact of climate change to the wind potential and in turn to the wind power production is recommended.

However, for the purpose of comparison with the impacts induced on the other sectors and only, it is suggested that:

- the impact on wind power can be characterized rather insignificant, since the contribution of wind power to the total electricity production is rather small (~2%) and in general, according to the international bibliography no significant changes are expected in wind potential on a worldwide basis.

[35] The data are available at: http://www.cera.org.cy/main/data/articles/wind.pdf. In order to estimate the share of electricity production from wind power the amount of electrical energy (kWh) produced during 2010 (5,205 GWh, see Section 11.2.1.4) was used.
[36] The corresponding share for the year 2010 was 0.6%

11.3.1.1.3 Solar energy

The climate factors that can affect solar insolation are the following:

- Cloudiness;
- Atmospheric aerosol composition;

Generally, solar insolation drops with the increase of the above factors. However, due to the complex relationship between these factors and the magnitude of the potential impact, it is unclear whether the effects of climate change will result in reduced solar insolation (Kirkinen, 2005).

In addition, it must be noted that temperature has an impact on the efficiency of the photovoltaic cells and in specific higher temperature results to reduced power production.

Situation in Cyprus

Cyprus is one of the most favorable areas worldwide in terms of solar potential.

Various solar applications have already been installed, including:

- Active solar systems;
- Power production systems.

In order to study the observed impacts, if any, on the yields of the systems mentioned above it is essential to study first the observed changes in solar potential due to climate change.

The composition of the atmosphere is being observed by the Meteorological Service of Cyprus since 1990. The number of days with dust in suspension presents an increasing trend over time as depicted by the following diagram.

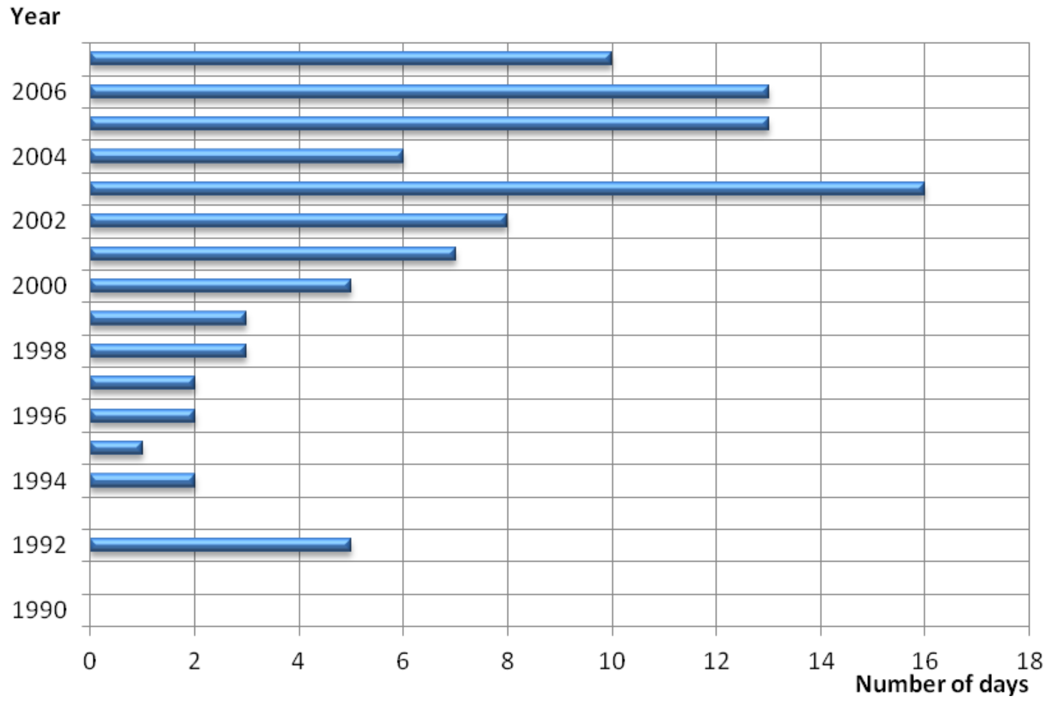
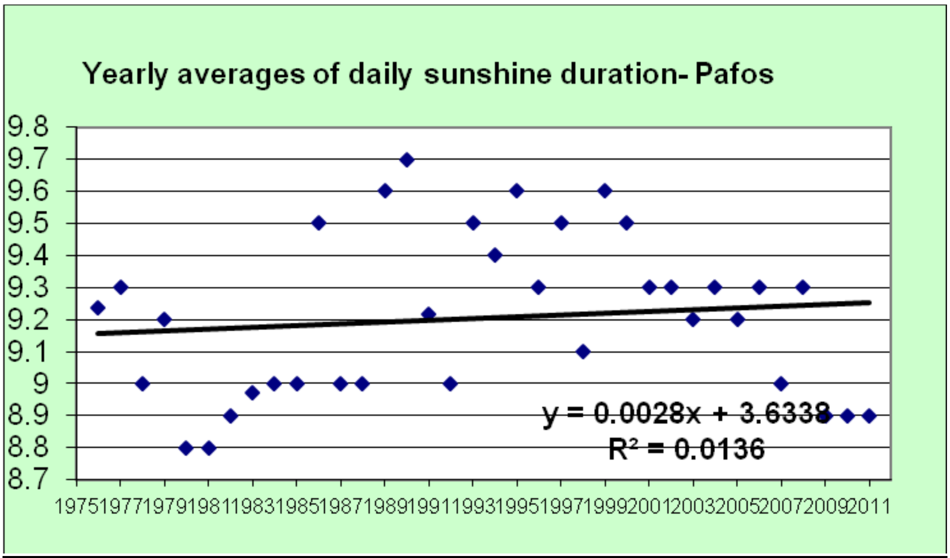


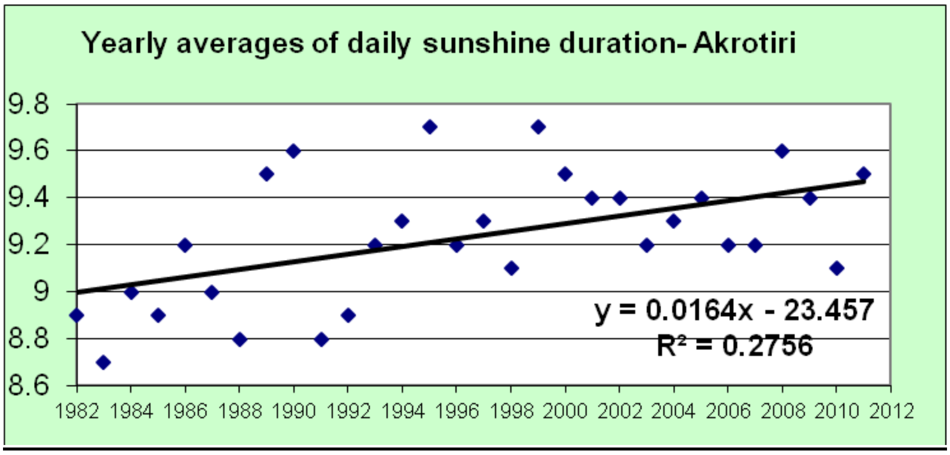
Figure 11-9: Number of days with dust in suspension in Cyprus between 1990 and 2007.

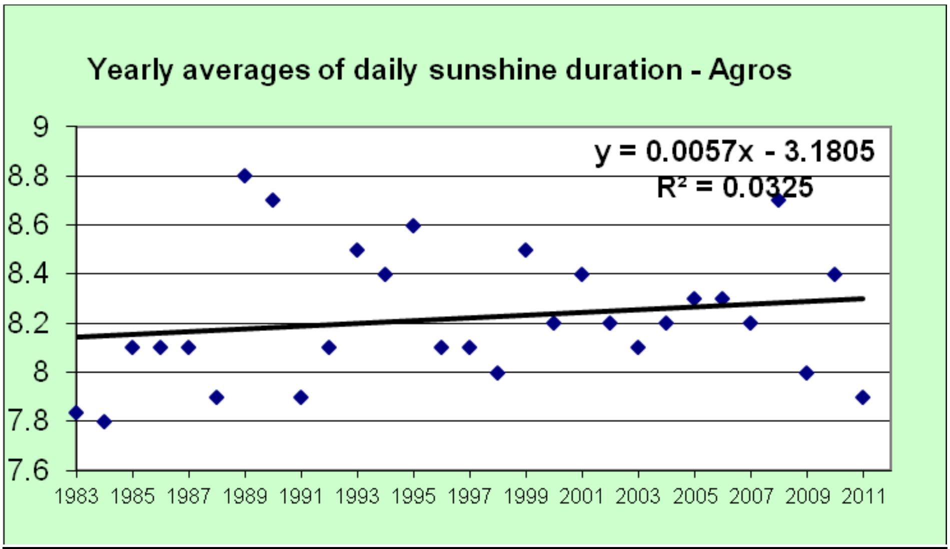
Source: Pashiardis, 2011

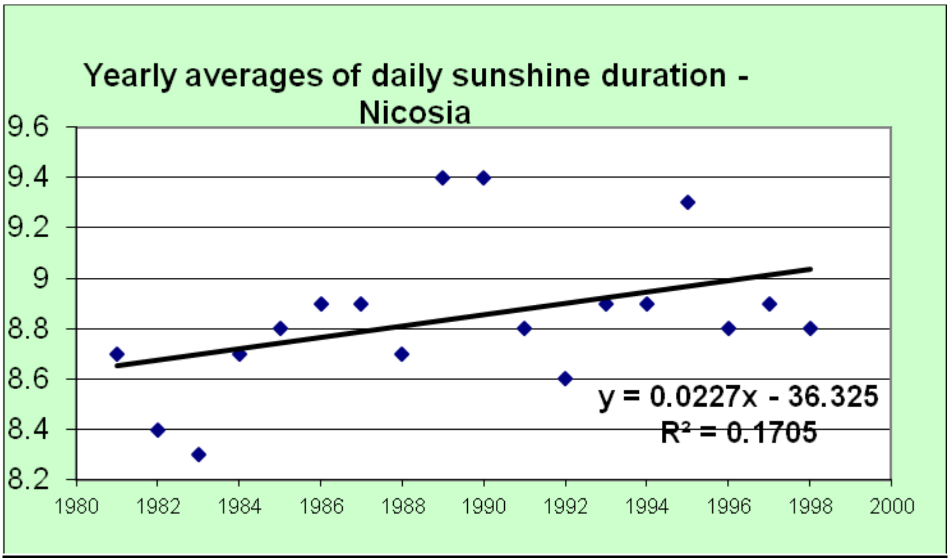
However, no changes in solar insolation have been linked with changes related to dust concentration in the atmosphere.

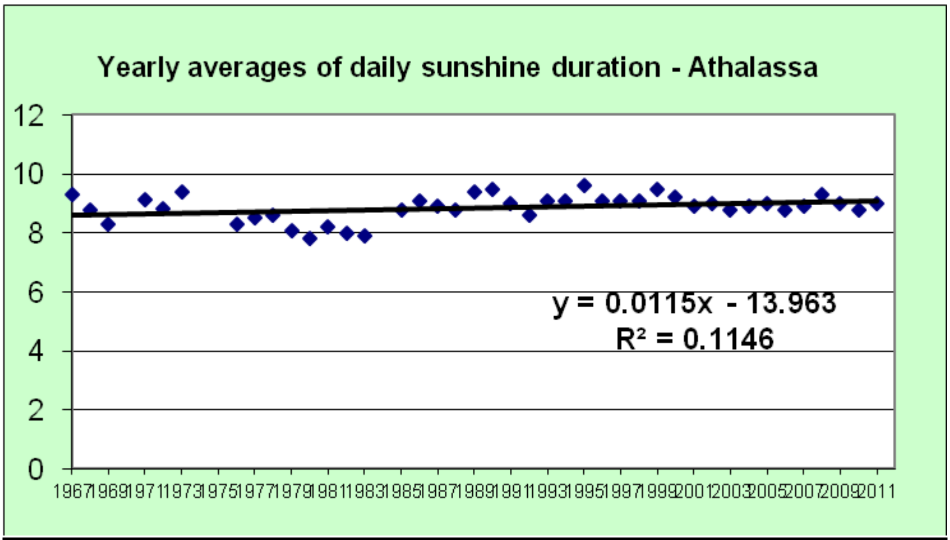
According to the Meteorological Service of Cyprus, the daily average sunshine has exhibited an increasing trend over the last decades (see Figure 11-10).

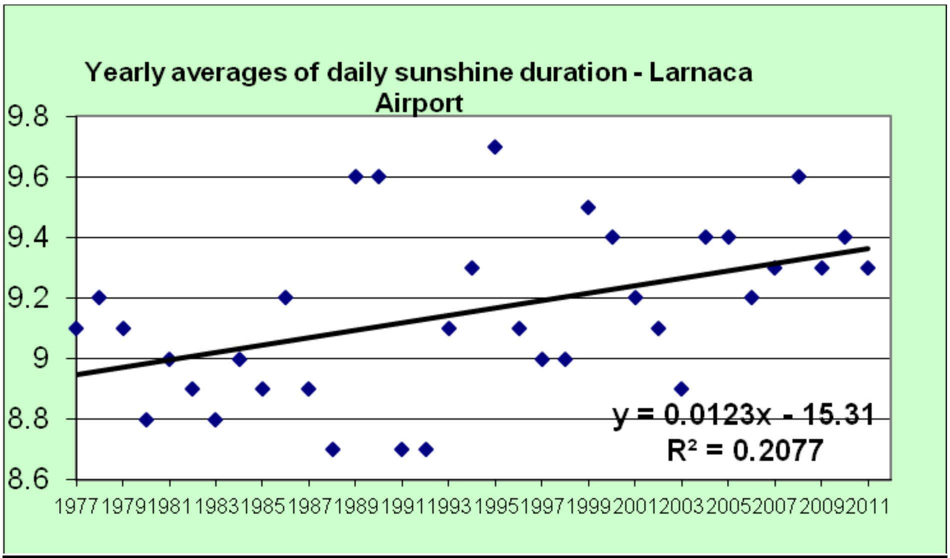



Yearly averages of daily sunshine duration- Akrotiri
y = 0.0164x - 23.457
R² = 0.2756
9.8
9.6
9.4
9.2
9
8.8
8.6
1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012


Yearly averages of daily sunshine duration - Agros
y = 0.0057x - 3.1805
R² = 0.0325
9
8.8
8.6
8.4
8.2
8
7.8
7.6
1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011


Yearly averages of daily sunshine duration - Nicosia
y = 0.0227x - 36.325
R² = 0.1705
9.6
9.4
9.2
9
8.8
8.6
8.4
8.2
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000





Source: The data was obtained through contacts with the Meteorological Service of Cyprus (Contact Person: Stelios Pashiardis)

Figure 11-10: Yearly averages of daily sunshine duration observations between 1977 and 2011 in Cyprus

Active solar systems

Active solar systems have been widely used in Cyprus with main representative application, the production of hot water. According to the Reviewed National Sustainable Development Strategy 2010, (MANRE, 2010), 92% of households and 53% of tourist accommodation units cover their hot water needs with renewable solar energy. In order for this energy conversion to be realized, solar thermal collectors are employed (mostly flat-plate collectors). Actually, Cyprus is a pioneer in this kind of applications, as it ranks first (see Figure 11-11) on a European level, in installed collectors per capita (~1m^2/capita).

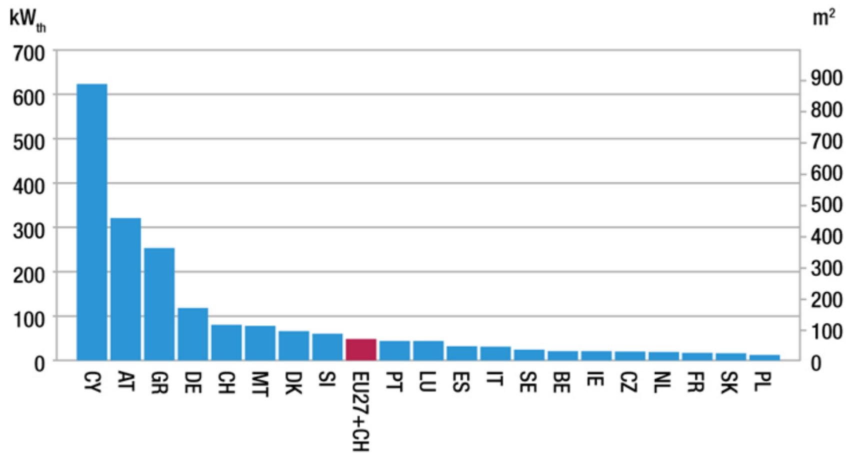


Figure 11-11: Solar thermal capacity in operation (per 1000 capita). Source: ESTIF, 2011

No impacts have been observed on solar power production due to climate change.

As relative research is still lacking, further work in the field is recommended.

Similarly to what was noticed for wind power production, it seems that:

- the impact of climate change on solar power can be characterized rather insignificant.

Electrical power production

At present, the only application of this type is the photovoltaic generator. Currently, the installed capacity has risen due to the supporting financial tool under the Grant Scheme for the promotion of RES. The development of PV systems is illustrated in Figure 11-12, between 2006 and 2011 (data obtained by: http://www.cera.org.cy/main/data/articles/pv.pdf).

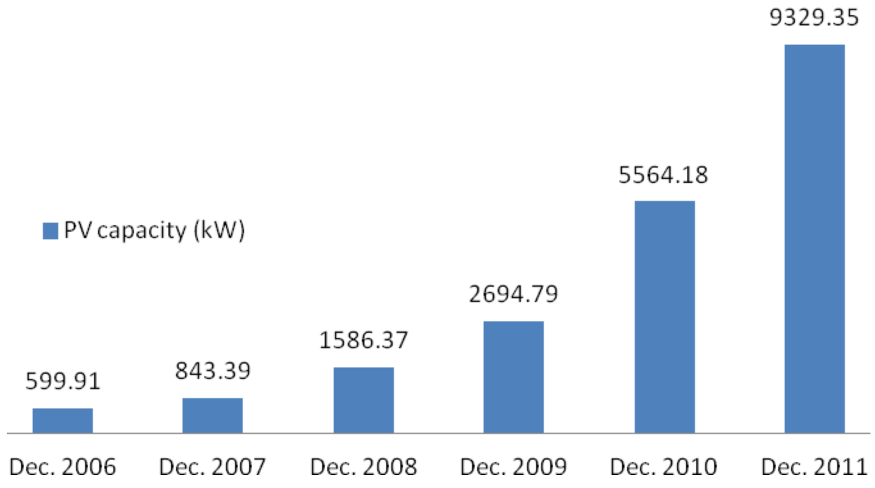


Figure 11-12: Total installed PV capacity (MW) in Cyprus

Finally, the number of opinions expressed by the competent authority of Cyprus (Department of Environment) for PV applications between 2009 and 2012 are presented in the following table.

Table 11-4: Number of opinions for PV applications received between 2009 and 2012

	2009	2010	2011	2012
=<100KW	11	60	54	27
>100KW	8	53	61	25

Finally, it must be noted that even though concentrating solar power (CSP) has not been developed until now, it is estimated that it will play a significant role in power production in the coming years.

- **Total installed capacity (December 2011):** 9,329.35 kW
- **Electricity PV production (2011):** 10.1 GWh[37]
- **Current share of electricity production from solar power**: 0.19%

Two licenses for CSP systems with a total capacity of 50MW have been already issued from the Cyprus Energy Regulatory Authority until now.

No impacts have been observed due to climate change.

[37] The data are available at: http://www.cera.org.cy/main/data/articles/pv.pdf (p.3). In order to estimate the share of electricity production from wind power the amount of electrical energy (kWh) produced during 2010 (5,205 GWh, see Section 11.2.1.4) was used.

11.3.1.1.4 Bio - energy

Biomass is the result of photosynthetic activity of plant organisms that transform solar energy into a series of processes and raw materials water minerals and carbon dioxide. The main forms of biomass for non-food purposes are:

- agricultural by-products which can be:
  - residual agricultural crops (maize strains, cereal straw etc.);
  - waste processing agricultural products (fruit pits, olive pits, rice hulls, etc.)
- animal farming wastes;
- wood biomass;
- energy crops and industrial plants (reed, miscanthus, sweet sorghum, eucalyptus, etc.); and
- the organic fraction of municipal solid waste.

The forms of biomass that could be affected by climate change are the energy crops and wood biomass used for space heating: the likely effects could be: land degradation and soil erosion; lower yields from crop damage and failure; increased risk of wildfire; loss of arable land.

Situation in Cyprus

CERA has already issued 17 licenses for the construction of anaerobic digesters of farming wastes for electricity production from biogas, with total capacity of 14.9 MW and is examining two applications of 3.2MW total capacity. The development of biomass systems is illustrated in Figure 11-13, between 2006 and 2011.

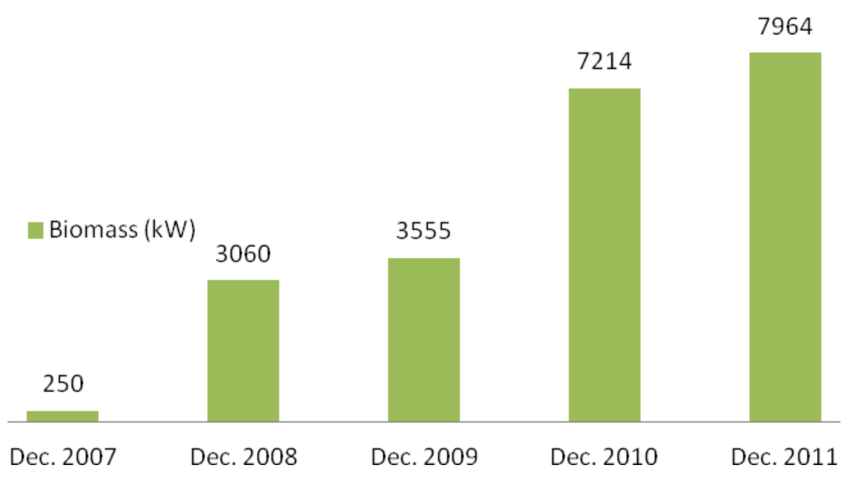


Figure 11-13: Total installed capacity (MW) of biogas plants in Cyprus.

- **Total installed capacity (December 2011):** 7,964 KW
- **Electricity production (2011):** 39.7 GWh[38]
- **Current share of electricity production from bio - power**: 0.8%

No impacts have been observed on bio-power production due to climate change.

As relative research is still lacking, further work in the field is recommended.

Given that the electricity production by biomass is not based on bio-crops which are most dependent by climate change, in conjunction with the very little contribution of bio-power in electricity production, the impact on the sector induced by bio-power seems to be rather insignificant.

Heat production from biomass

Results of a recent research study showed that 35% of the households in the mountainous communities in Cyprus utilize traditional fireplaces for space heating. The following figure shows the origin of biomass in the mountainous communities:

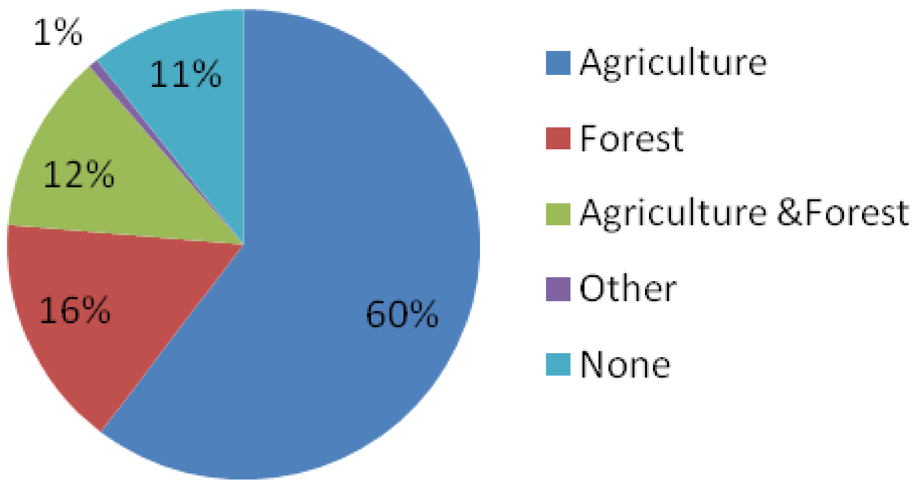


Figure 11-14: Origin of wood biomass in Cyprus

Bio-fuels

38 The data are available at: http://www.cera.org.cy/main/data/articles/biomass.pdf. In order to estimate the share of electricity production from wind power the amount of electrical energy (kWh) produced during 2010 (5,205 GWh, see Section 11.2.1.4) was used.

The bio-fuels have entered the market of transport fuels since 2007. The recorded bio-fuel consumption between 2007 and 2009 is presented in Figure 11-15. According to a Ministerial Decision all suppliers of petroleum products are obliged to mix bio-fuels in conventional fuels so that the net annual amount of bio-fuels in the conventional fuels be at least 2.4% (around 6-7% biodiesel per volume in the conventional diesel).

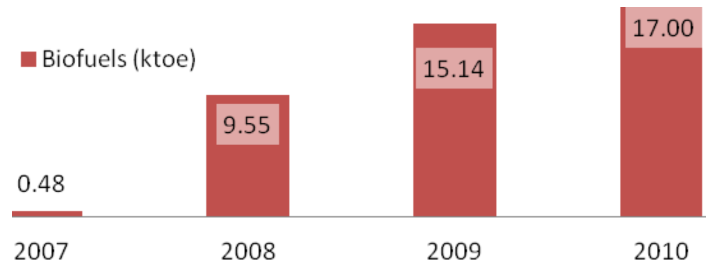


Figure 11-15: Bio-fuel consumption (ktoe) between 2007 and 2009

In Cyprus only, one company has been activated in the bio-fuel production sector, with 7,460 tn for the year 2008 (Kassinis, 2009), while according to more recent data the respective production for the year 2011 totals 6,381tn.

11.3.2 Efficiency of thermal power plants

In order to obtain a better understanding of the correlation of temperature with the power plants efficiency, the thermodynamic efficiency of the Carnot cycle can be used:

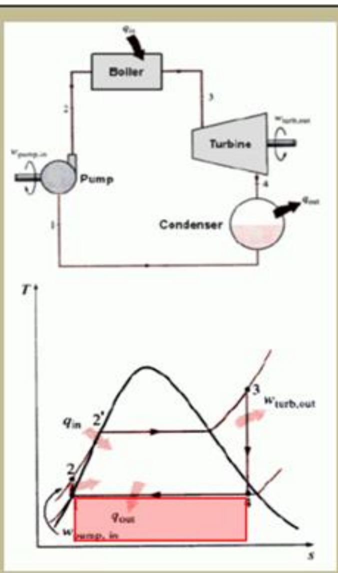
$$n_{th,Carnot} = 1 - \frac{T_b}{T_a}$$

(11-2)

Where:

- T_b, the temperature where the heat rejection occurs; and
- T_a, the temperature (K) at which heat is transferred to the working media.

From the equation, it can be easily deduced that with increased cooling temperatures (T_b) the thermodynamic efficiency of the power generation cycle decreases. It must be noticed that the reduction of the coefficient of efficiency is not dependent on the type of cooling technology employed. However, in order to minimize this impact, the selection of the appropriate technology must be made on a case specific basis. The BREF document regarding the best available techniques on the large combustion plants, provides concrete data for such a selection (EC, 2006; pp. 46-47).



Box 3.1: Heat rejection of an ideal Rankine cycle (steam power cycle, see also Figure below)

According to the second law of thermodynamics the heat flux can be expressed by:

$$Q = \int_{s_1}^{s_2} T \cdot ds$$

Given, that in the heat rejection section latent heat is rejected (the temperature remains constant) the equation is simplified as follows: $Q = T \cdot (s_2 - s_1)$. This product represents the area which is highlighted in the figure on the left. That is to say, the higher the temperature, the higher the corresponding area of the diagram, translating to higher energy losses.

Moreover, in order to attain the same cooling effect with increased temperatures, larger quantities of the cooling medium have to be used. This is translated into higher pumping requirements which lead to decreased net power plant capacity. As it can be seen from Figure 11-17, the net electricity offered to the public network equals to the gross electricity produced minus the own electrical consumption of the power plant. To this end, the capacity of the power plants is expected to decrease.

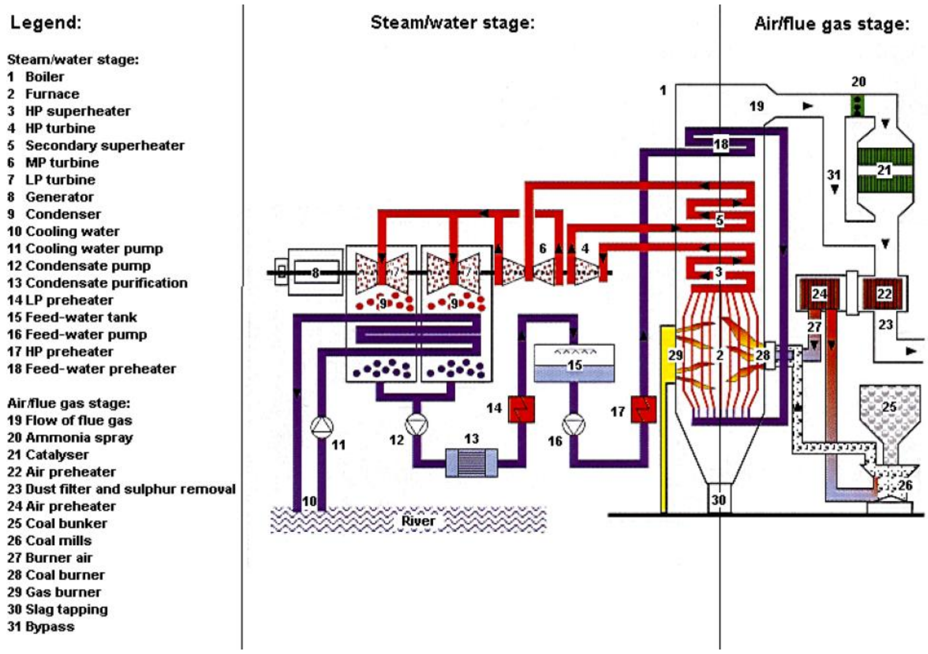


Figure 11-16: Possible configuration of a steam plant

Source: EC, 2006

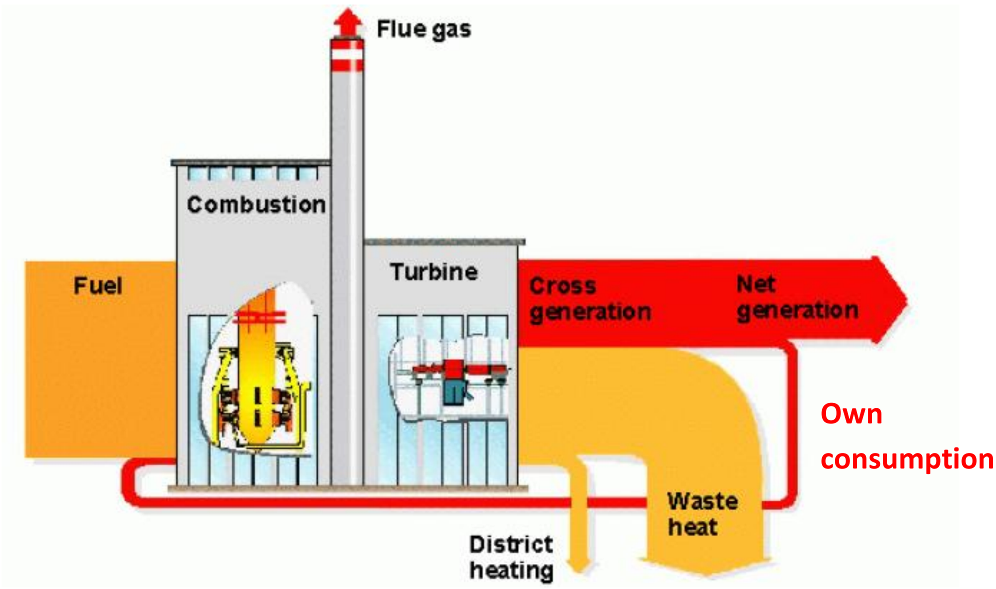


Figure 11-17: Energy conversion in a typical thermal power plant

Source: EC, 2006

Situation in Cyprus

- Monitoring of climate factor:

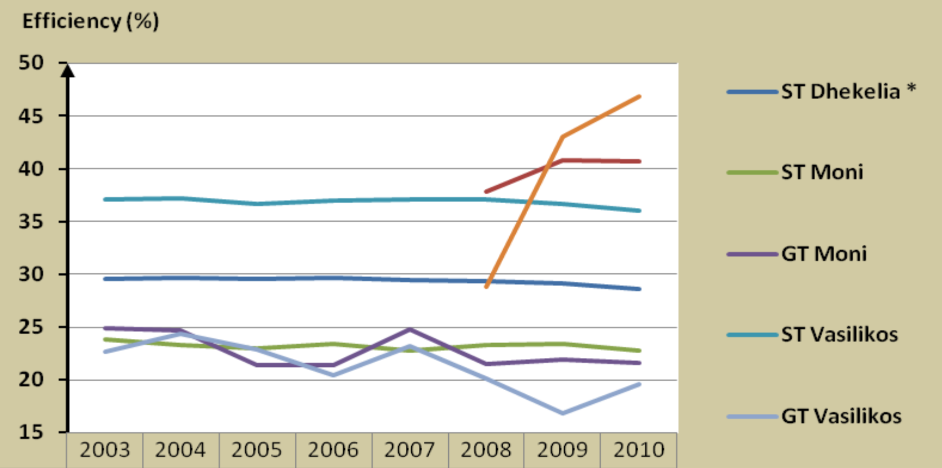
Temperature increase: 0.8°C (during last century)[39]

Impact on sector:

Indicators:

- **Thermal coefficient of efficiency : 36.1%**[40]

Apart from the mean value (36.1%), the efficiency of each unit should be monitored. The changes that have been recorded in the efficiency of the different thermal power plants are presented in Figure 11-18. It must be noted that the data presented have been obtained through communication with Electricity Authority of Cyprus (EAC) and have not been published yet.



	2003	2004	2005	2006	2007	2008	2009	2010
ST Dhekelia *	29.543	29.710	29.592	29.702	29.444	29.333	29.146	28.635
ST Moni	23.850	23.330	22.999	23.420	22.824	23.278	23.364	22.771
GT Moni	24.882	24.674	21.433	21.394	24.810	21.478	21.919	21.605
ST Vasilikos	37.055	37.192	36.655	36.946	37.090	37.099	36.673	36.036
GT Vasilikos	22.660	24.368	22.873	20.485	23.165	20.160	16.883	19.636
ICE Dhekelia						37.790	40.774	40.703
CCGT Vasilikos						28.847	43.066	46.891

Figure 11-18: Observed changes in the efficiency of thermal power plants in Cyprus

*Note: (1) CCGT: Combined Cycle Gas Turbine, ST: Steam Turbine, GT: Gas Turbine, ICE: Internal Combustion Engine, (2) the increase in CCGT and ICE units are related with the installation of new units

[39] *Source: Meteorological Service of Cyprus*

[40] Average system efficiency (2010), estimated for all three EAC's power stations. The mean efficiency value increased by 1.76% from 2009 to 2010 (34.32% and 36.08% respectively), as EAC utilized at the greatest possible extent the Vasilikos and Dhekelia units, which present higher efficiency values, in order to meet the basic load requirements. (**EAC, 2011**)

As obvious by the above figure, the efficiency of the thermal power plants drops over time. However, from the communication with the EAC's competent department[41], it was deduced that:

- there is no clear relation between climate change (temperature increase) and drop of the thermal coefficient of the power plants in Cyprus, as the latter would still drop over time due to ageing of the power units.

As relative research is still lacking, further work in the field is recommended. No impacts have been observed on the efficiency of thermal power plants due to climate change.

11.3.3

11.3.4 Energy demand for cooling and heating

One of the most critical climate-induced changes is the rise of the global average surface temperature. Warming of the climate system is unequivocal according to IPCC (IPCC, 2007) while the expected increase in temperature will vary across regions and season, causing changes in the demand for electricity and heat.

In order to allow the impact on energy demand to be measured, counteracting effects should be carefully taken into account such as cooling and heating degree days. Countries with low latitudes as Cyprus will be significantly affected in terms of cooling demand, resulting in an increase of cooling degree days with increased temperature.

In the Mediterranean basin, the expected change in energy demand is expected to change by 2050 as follows (Alcamo, 2007):

- 2 to 3 fewer weeks per year will require heating; and
- additional 2 to 5 weeks will require cooling.

Situation in Cyprus

- Monitoring of climate factor:

Temperature increase: 0.8^{o}C (during last century)[42]

[41] Contact person: Menelaou Charalambos (Assistant Generation Manager), Tel: 00357 22 201513, CMenelao@Eac.com.cy

[42] Source: *Meteorological Service of Cyprus*

- Impact on sector:

  Indicators:

  - **Heating degree days (1980-2005)[43]:** **~268 fewer HDD**
  - **Cooling degree days(1980-2005):** **101 additional CDD**
  - **Maximum output capacity (2010):** **1,438 MW**
  - **Peak demand (2010):** **1,148 MW[44]**
  - **Energy generation (2010):** **5,205 GWh[45]**
  - **Energy use (kg oil equivalent/capita):** **2,298[46]**

Heating and Cooling Degree Days

The observed changes in heating and cooling degree days between 1980 and 2005 are presented in: (a) Figure 11-19 to Figure 11-21, for heating degree days and (b) Figure 11-22 to Figure 11-24 for cooling degree days. The data presented in the figures have been obtained through contacts with the Meteorological Service of Cyprus[47]. More specifically, the data were selected by three meterological stations which are situated in different elevation levels. This data will allow to obtain a better understanding of the relation between change in heating/ cooling demand and climatic zones (mountainous, low land and coastal areas). These stations are: (a) Prodromos Station (mountainous area); (b) Athalassa (low land area); and (c) Larnaca Airport (A/P) Station (coastal area).

For the figures under discussion the following apply:

- **Heating degree days**: a drop of 267.9 HDD between 1980 and 2005 has been observed (base temperature=20^{o}C); and

- **Cooling degree days**: an increase of 101.0 CDD between 1980 and 2005 has been observed (base temperature=26^{o}C).

For estimating the change in cooling/heating degree days the regression equations presented in the above figures were used. More specifically, the values presented comprise mean values of the changes observed in the three meteorological stations (see also Section 11.4.3.1).

Peak Demand

[43] See also Section 11.4.3.1 (Table 11-7)

[44] The peak demand increased by 4.6% from 2009 to 2010 (1,098MW and 1,148MW respectively) (**EAC, 2011;** p. 11)

[45] This figure refers to the gross generation (2010), while the sales of electricity totaled 4,781,972 MWh (~4,782 GWh, 91.8% of gross generation) (**EAC, 2011;** p. 11)

[46] http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE/countries/1W-CY?display=default

[47] Contact person: Stelios Pashiardis, e-mail: spashiardis@ms.moa.gov.cy

The peak demand in 2010 amounted to 1,148 MW reflecting an increase of 4.6% from 2009 (1,098MW) while the minimum demand for the same year totaled 306 MW, as shown in Figure 11-25. In the same figure a diurnal variation of the power demand is presented.

With reference to the seasonal variation of the power demand (see Figure 11-27), high energy consumption seen during winter (December - January) is associated with increased heating requirements due to low air temperatures. During spring, energy consumption remains stable and starts to increase gradually towards the end of spring (May). During summer the energy consumption reaches its peak on July. These maxima of energy consumption, which are much larger than those of winter, associated with increased energy demand for cooling and come mainly from the extensive use of air conditioners. From late summer (August) until late fall (November) temperature gradually falls, and energy requirements are reduced (Giannakopoulos et al., 2010).

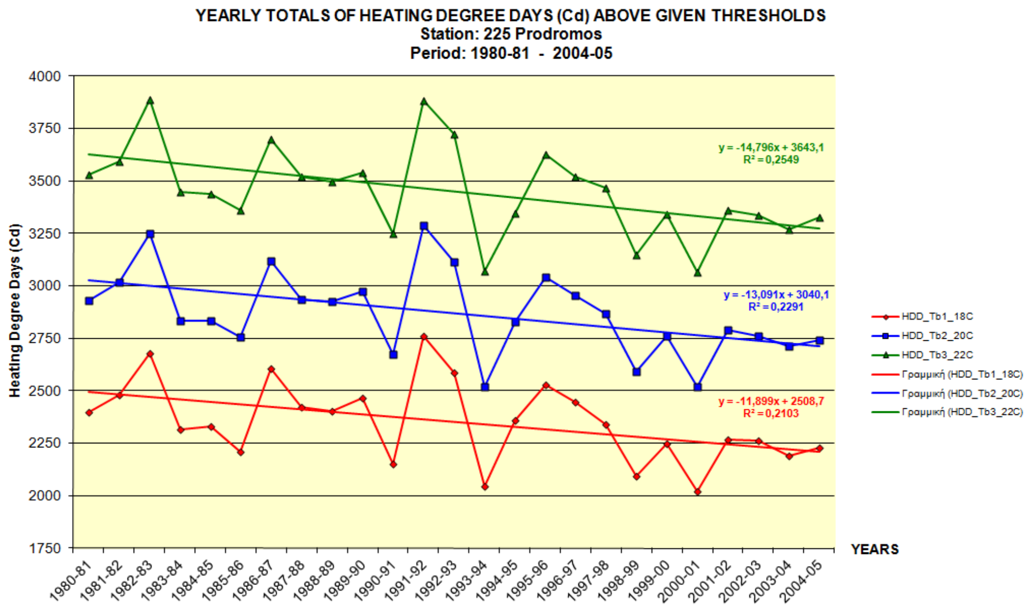


Figure 11-19: Observed changes in heating degree days between 1980 and 2005. Station: 225 Prodromos

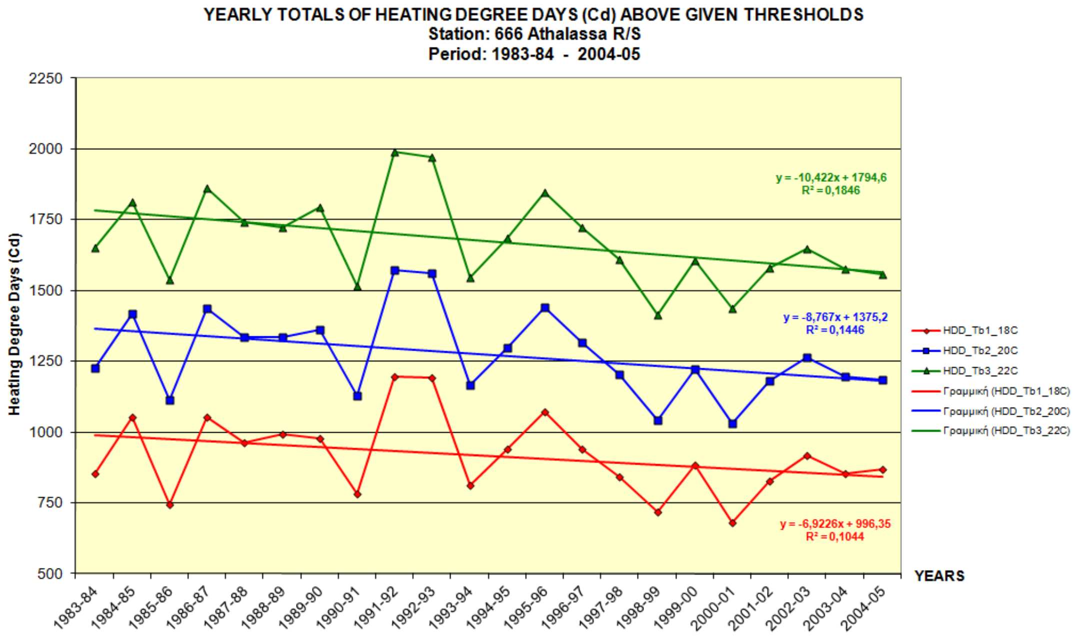


Figure 11-20: Observed changes in heating degree days between 1980 and 2005. Station: Athalassa R/S

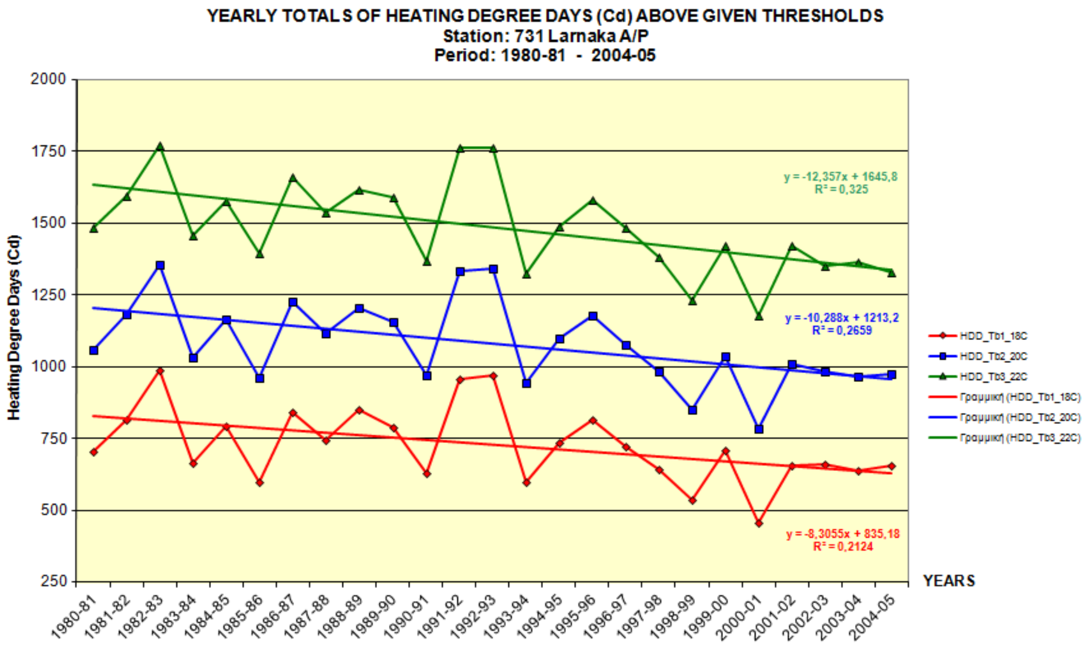


Figure 11-21: Observed changes in heating degree days between 1980 and 2005. Station: 731 Larnaca A/P

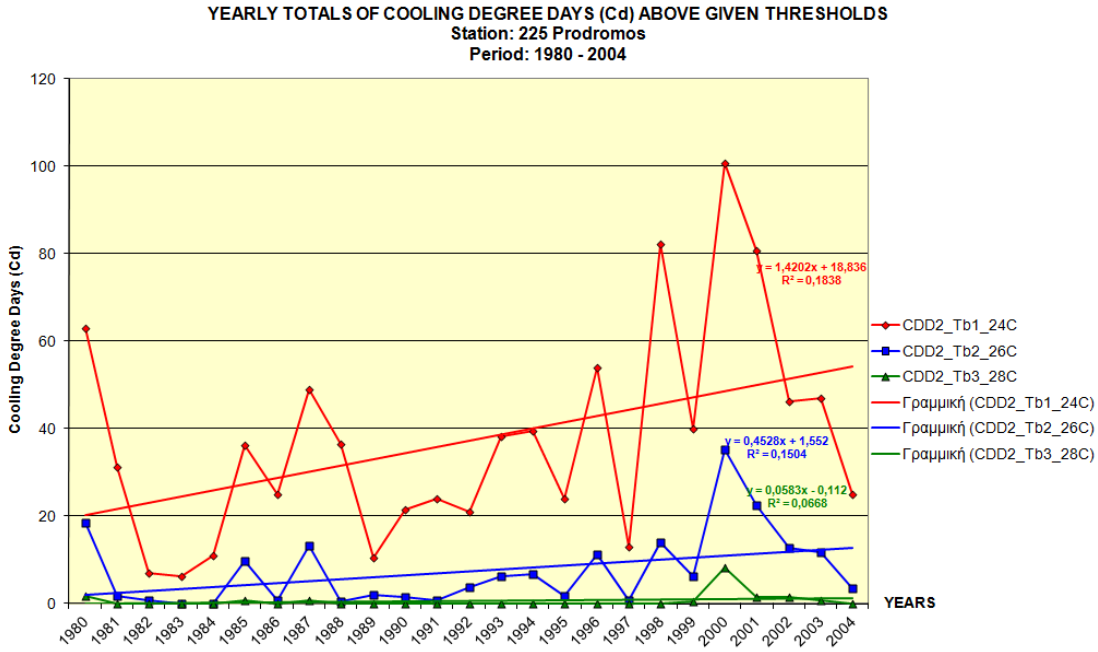


Figure 11-22: Observed changes in cooling degree days between 1980 and 2005. Station: 225 Prodromos

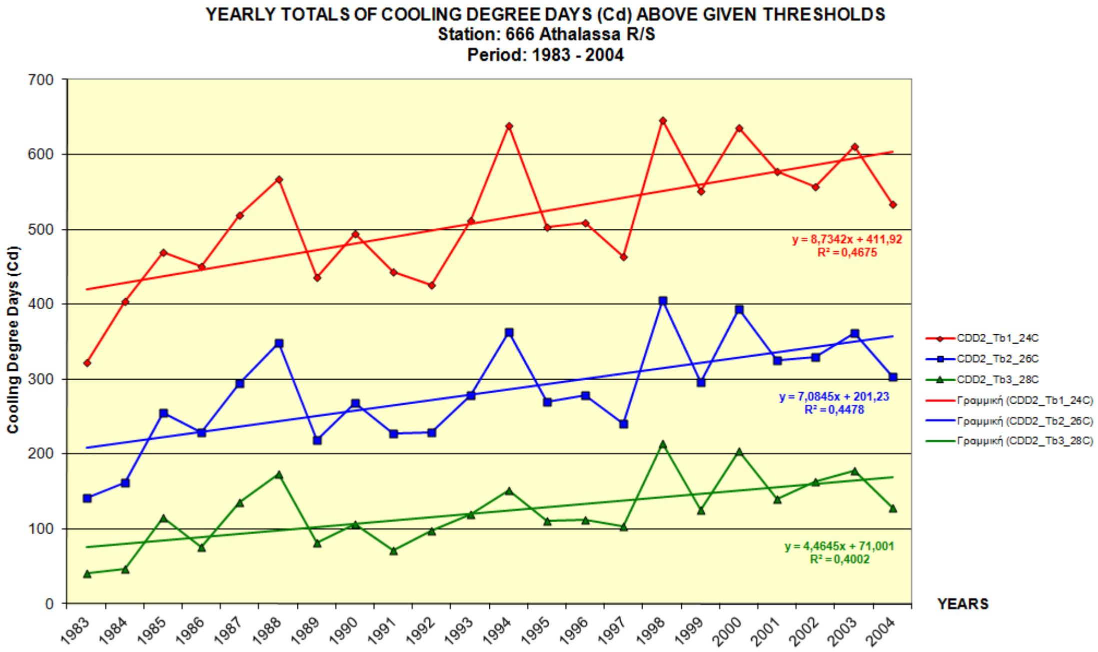


Figure 11-23: Observed changes in cooling degree days between 1980 and 2005. Station: 666 Athalassa R/S

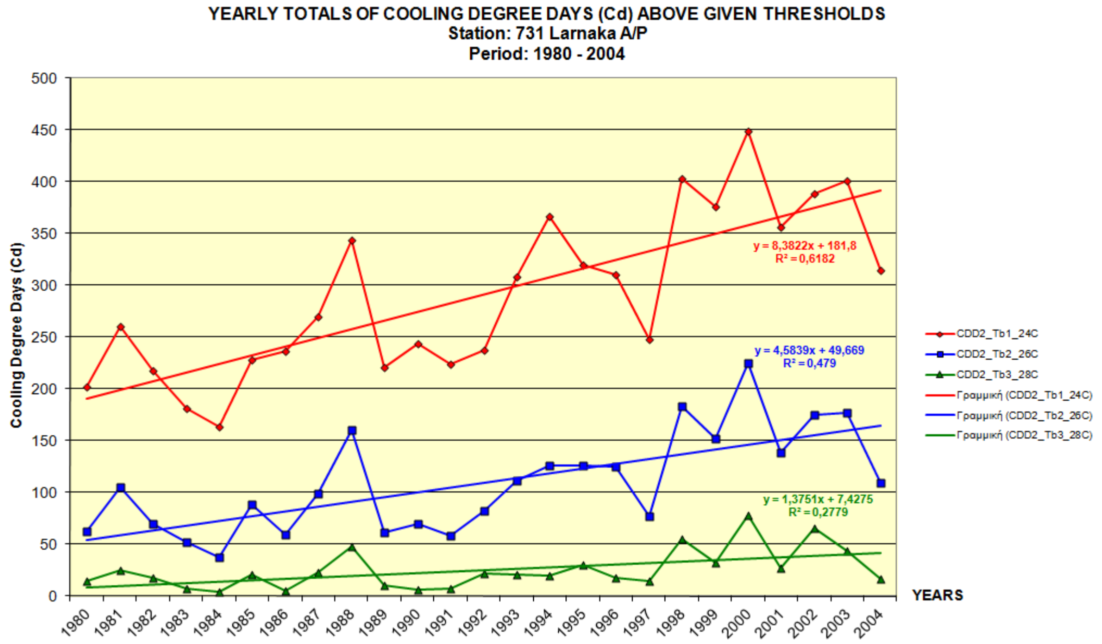


Figure 11-24: Observed changes in cooling degree days between 1980 and 2005. Station: 731 Larnaca A/P

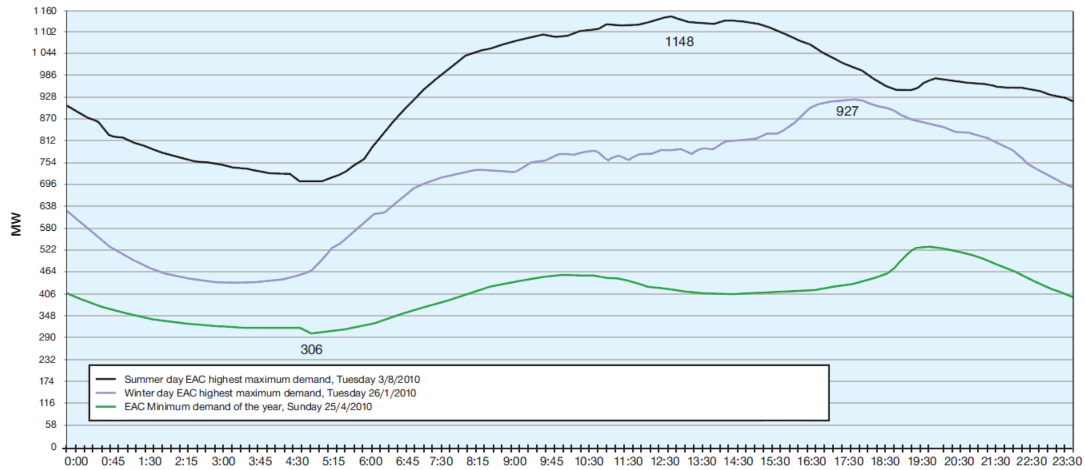


Figure 11-25: Peak and minimum demand in Cyprus in 2010

Source: EAC, 2011

Energy generation

Energy requirements are linked to climate conditions and the relationship of energy demand and temperature is not linear (see Figure 11-26). The variability of ambient air temperature is closely linked to energy consumption, whose maximum values correlate with the extreme values of air temperature (maximum or minimum) (Giannakopoulos et al., 2009).

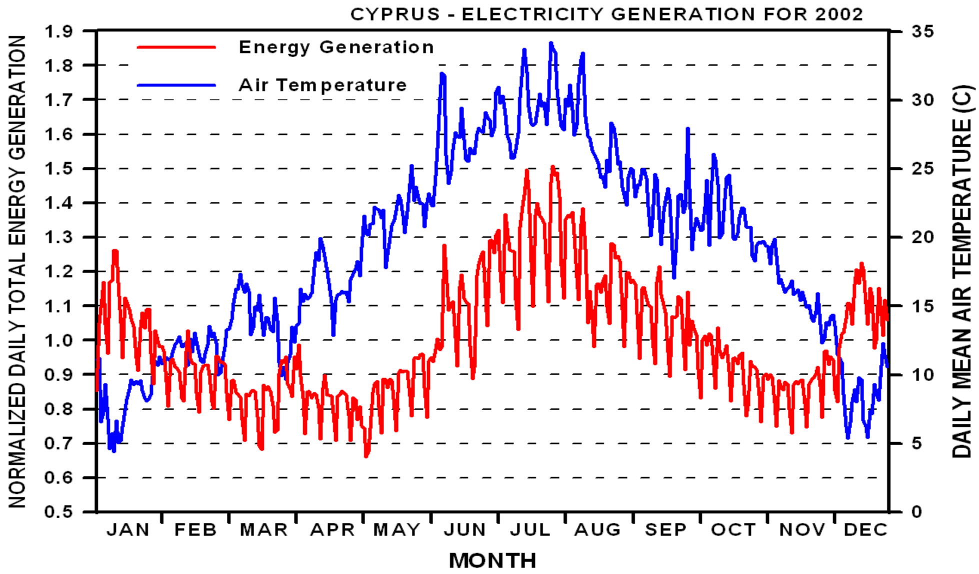


Figure 11-26: Daily mean air temperature and daily total energy generation for Cyprus for the year 2002

Source: Giannakopoulos et al., 2010

Due to the observed warming in Cyprus in our days, energy consumption above, may change as energy requirements for heating during winter will fall while during summer energy demand for cooling will grow largely due to high temperatures. This constitutes the most important impact of climate change in relation to energy because, since the energy consumption has increased in recent years (see Figure 11-28), further increasing demand for energy during summer should somehow be offered. This means there will be a need to install additional generating capacity over and above that needed to cater for the underlying economic growth.

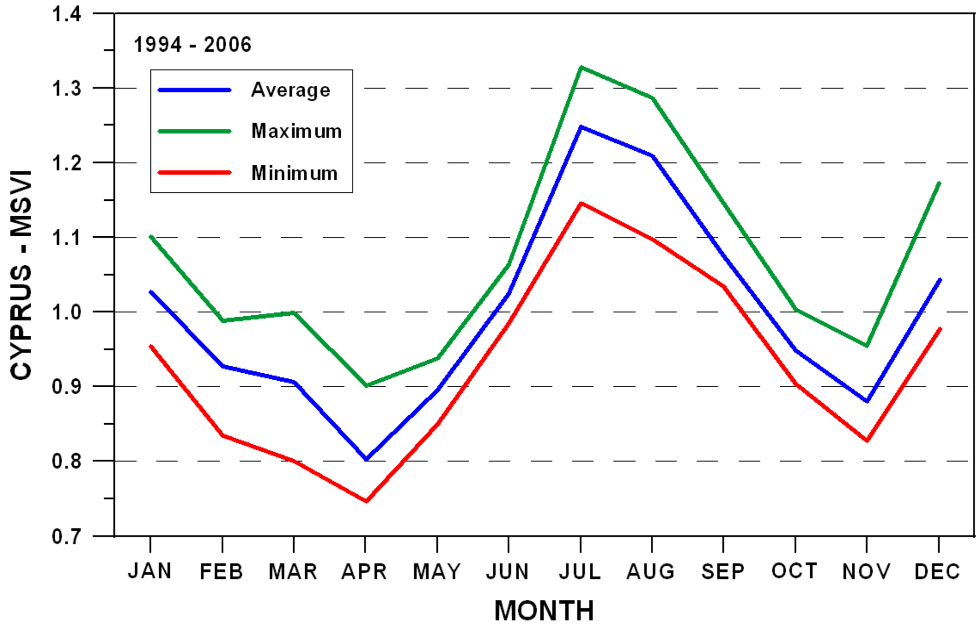


Figure 11-27: Mean monthly seasonal variation index (MSVI) of electricity consumption in Cyprus for 1994-2006

Source: Giannakopoulos et al., 2010

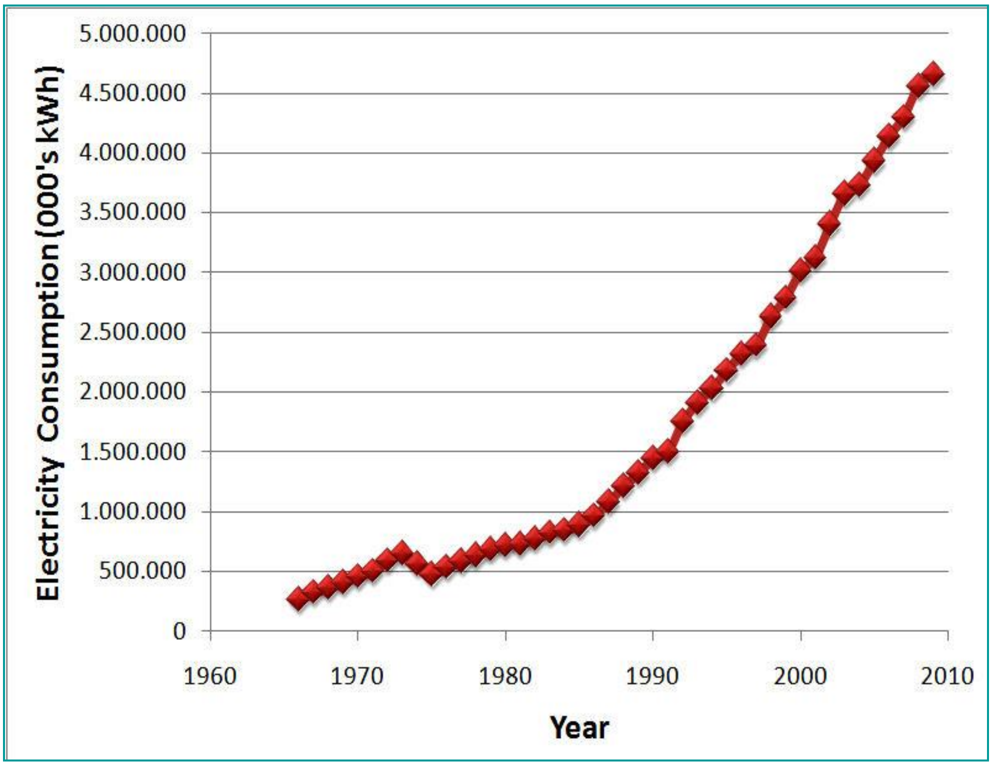


Figure 11-28: Increase in mean monthly electricity consumption in Cyprus for the period 1966-2009

Source: Lange, 2011a

Energy use

According to Worldbank data, energy use in Cyprus expressed as kg of oil equivalent per capita for 2009 was 2,298 kg oil eq./cap, which was higher compared to the corresponding value of 1,802.6 kg oil eq./cap on a worldwide basis.

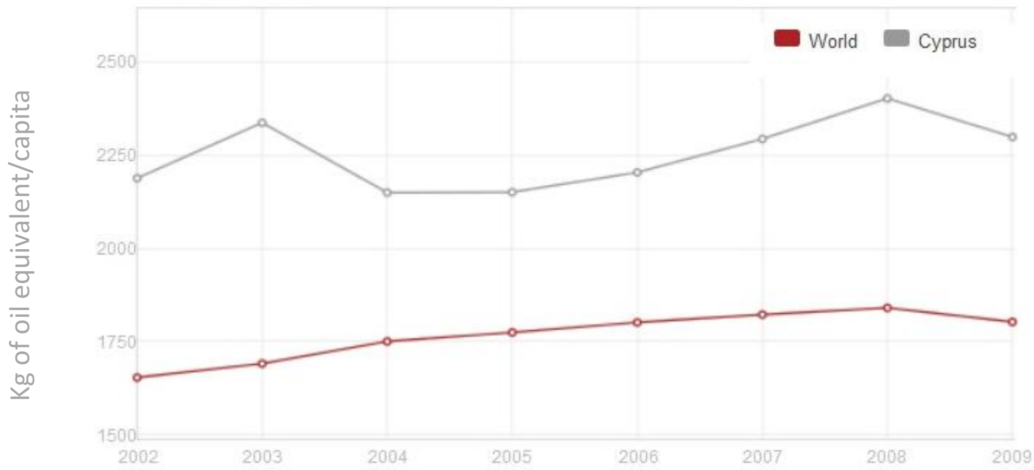


Figure 11-29: Energy use (kg of oil equivalent/capita) in Cyprus.

Source: http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE/countries/1W-CY?display=graph

11.3.5 Pressures on the energy sector

11.3.5.1 Energy production cost

The energy production cost depends on the following elements (EAC, 2011):

– Fuel oil:	63%
– Greenhouse gas emission rights:	0.9%
– Salaries and related costs:	15.6%
– Deficiency contribution to pension schemes:	1.7%
– Materials, services and other expenditure:	8%
– Depreciation:	10.8%

- Impact on sector:

  Indicator:

  - **Energy production cost (EAC, 2011):** **0.14598€/kWh**

The energy production cost increased by approximately 26% from 2009 to 2010 (0.1159€/kWh and 0.14598€/kWh[48] respectively), mainly reflecting the increase (27.4%) in oil price (EAC, 2011). The price of oil shows a rising trend between 2009 and 2010, as depicted in Figure 11-30.

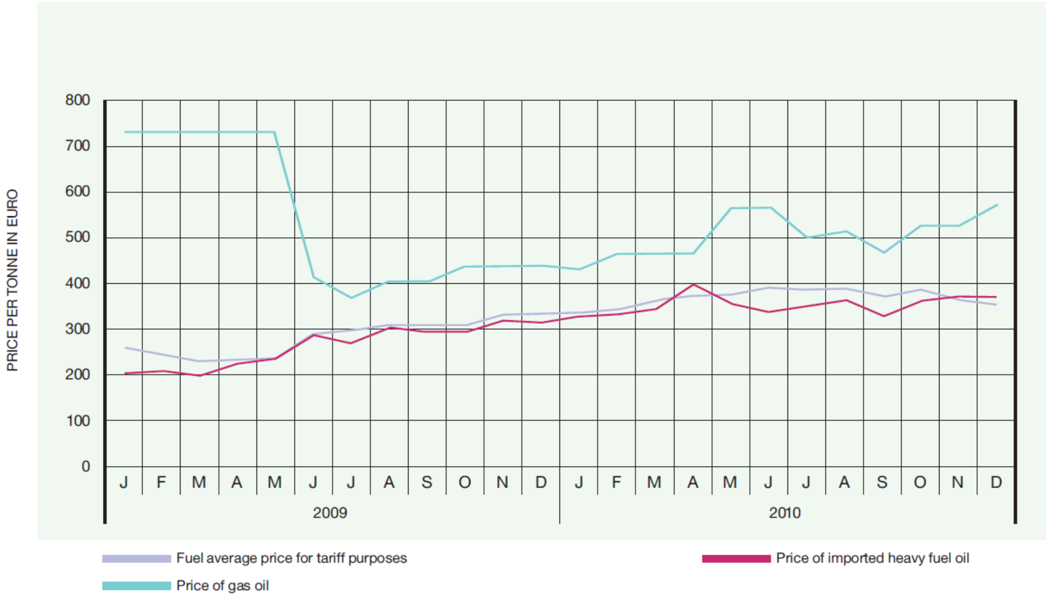


Figure 11-30: Fuel price between 2009 and 2010

Source: EAC, 2011

As analyzed in the following chapter, Cyprus shows particular vulnerability on the energy sector stemming from oil prices as the total amount of oil used is imported.

11.3.5.2 Energy demand for water production from desalination plants

The rainfall decrease as well as the prolonged droughts has resulted in freshwater shortage in dams creating serious problems in terms of water availability in large urban and tourist centers as well as in agriculture. To reduce the dependence of drinking water on rainfall, the Government of Cyprus has resorted to operating seawater desalination plants which produce large amounts of fresh water to address the needs (WDD, 2011b).

Although seawater desalination seems to be a fairly satisfactory method of producing fresh water, it is a very energy-demanding process and therefore raises the issue of energy production required especially during the summer where energy demand is already at the highest level (due to air conditioners). The energy required to desalinate water is about 4.5 kWh/m^3 (Lange, 2011). Taking into account that a significant part of drinking water supply (46.862.000 m^3/year, ~65%) is based on desalination (MANRE, 2010) and, in specific, Reverse

[48] Energy produced (2009): 5,133.3 GWh (EAC, 2011; p.11), total operating cost (2009): 595,095€ (EAC, 2011; p.76)

Osmosis (*RO*) plants, it is estimated that the aggregate electrical consumption for the operation of the three desalination plants in Cyprus totals 213,754.8 MWh/year (~4.4% of total electricity produced) (MANRE, 2010).

11.3.5.3 Energy demand for irrigation

It is expected that due to decreasing precipitation there will be longer irrigation periods. Since irrigated agriculture is based on pressurized irrigation systems and long conveyance pipe works, an increase in demand for electricity is expected.

11.4 Vulnerability assessment

In this section, the vulnerability of the energy sector to climate change impacts is assessed in terms of its sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which the energy sector is affected by climate changes, exposure is the degree to which the energy sector is exposed to climate changes and its impacts while the adaptive capacity is defined by the ability of the energy sector to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The indicators used for the assessment of sensitivity, exposure and adaptive capacity of the Cypriot energy sector to climate change impacts are summarized in Table 11-5.

Table 11-5: Indicators used for the vulnerability assessment of climate change impacts on the energy sector of Cyprus

Vulnerability Variable	Selected Indicators
Renewable energy yield	
Sensitivity	– Change in renewable energy potential – Change in renewable power production
Exposure	– Share of hydropower in total power production – Share of bio-power in total power production – Share of wind power in total power production – Share of solar power in total power production – Increase in share of bio-power in total power production (2020) – Increase in share of wind power in total power production (2020) – Increase in share of solar power in total power production (2020)
Adaptive capacity	– Promotion of RES: Directive 2009/28/EC – Other measures undertaken (administrative, legal, economic, social measures)
Efficiency of thermal power plants	
Sensitivity	– Change of thermal coefficient of efficiency
Exposure	– Percentage of power plants affected

Vulnerability Variable	Selected Indicators
Adaptive capacity	- Adaptation measures implemented
Energy demand for cooling and heating	
Sensitivity	– Heating Degree Days (change 2005-1980) – Cooling degree days (change 2005-1980) – Peak demand (2010) – Energy use (2010) – Maximum output capacity (2010) – Energy capacity (2010) – Pressure on the energy sector o Energy production cost
Exposure	– Share of tertiary sector in the final energy consumption – Change of heating/cooling demand across regions
Adaptive capacity	– New power stations o Maximum output capacity (2016) o Peak demand (2016) o Energy capacity (2020) – Energy efficiency measures – Promotion of renewable energy power production – Natural gas introduction

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

To assess the vulnerability of the energy sector, the following impacts were considered:

1. Renewable energy yield;
2. Efficiency of thermal power plants;
3. Demand for electricity and cooling/ heating.

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability. In case additional data are provided by the competent authorities of Cyprus, the vulnerability of the sector could be re-assessed.

11.4.1 Renewable energy yield

11.4.1.1 Assessment of sensitivity and exposure

Sensitivity: Renewable power production is sensitive to climatic variation due to the reduction in renewable energy potential such as wind, solar and biomass.

In order to assess the sensitivity of RES power production to climate change the following indicators were used:

- Change in renewable energy potential; and
- Change in renewable energy production.

As discussed in detail in Sections 11.3.1.1.2, 11.3.1.1.3 and 11.3.1.1.4, relative research for monitoring the impact of climate change on wind, solar and bio-power production is still lacking and no conclusive information is available at present. The only available information is associated with the solar potential and it concerns the observations of the meteorological service of Cyprus regarding the composition of the atmosphere and the values of yearly average sunshine duration at different locations in Cyprus.

The observed changes in the daily sunshine duration are exhibiting a slightly increasing trend; something that indicates that the solar energy yields is expected to be slightly increased. The largest increase has occurred at the region of Athalassa, where the sunshine duration has increased from 8.66h (1967 data) to 9.16h (2011 data), exhibiting an increase of approximately 0.51h (see also Table 11-6).

Table 11-6: Observed changes in daily sunshine duration at different regions in Cyprus

Region	Increase in daily sunshine duration
Pafos	0.1h (increase from 1975 to 2011)

Region	Increase in daily sunshine duration
Akrotiri	0.5h (increase from 1982 to 2012)
Agros	0.16h (increase from 1983 to 2011)
Nicosia	0.45h (increase from 1980 to 2000)
Athalassa	0.51h (increase from 1967 to 2011)
Larnaca	0.42h (increase from 1977 to 2011)

It must be noted that the observed changes cannot be linked directly to climate change and thus further research on the field is required. However, it can be said that in general the sensitivity of RES energy production can be characterized as **limited to moderate**.

Exposure: In order to allow this factor to be measured, the indicators set in Section 11.3 shall be used.

The following indicators were used regarding RES power production (2010)[49]:

- Share of hydropower in total power production: 0%;
- Share of bio-power in total power production: 0.73%;
- Share of wind power in total power production: 0.65%; and
- Share of solar power in total power production: 0.13%.

The expected values of the aforementioned indicators for the year 2020 are the following (EEA, 2011):

- Share of hydropower in total power production: 0%;
- Share of bio-power in total power production: 1.9% (17MW, 143 GWh);
- Share of wind power in total power production: 6.8% (300MW, 499 GWh); and
- Share of solar power in total power production: 7.2% [(a) Photovoltaic: 192MW, 309 GWh; (b) CSP: 75MW, 309GWh].

  Note: The projections for the installed capacity and the yearly energy produced for 2020 by renewable energy sector are taken from the Ministry of Commerce, Industry and Tourism (MCIT, 2010, pp. 104-105).

[49] The percentages refer to the values in the column note with "c" expressing the share of the renewable technology in the sector total of the final gross energy consumption ('Additional energy efficiency scenario' only) (**EEA, 2011**; p.207))

On the basis of the values of the above-mentioned indicators, it can be said that the use of renewable power supply in the energy supply mix is expected to be significantly increased. However, as discussed in Section 11.3.1, the potential of the renewable energy sources in Cyprus, is not expected to present worth-noticing changes. To this end, the exposure was ranked as **limited**.

11.4.1.2 Assessment of adaptive capacity

Increase of RES installed capacity

The main policy measure related to renewable energy deployment in Cyprus is the Directive 2009/28/EC on the promotion of the use of energy from renewable sources. According to this Directive, each Member State has a specific target for the overall share of renewable sources in the gross final energy consumption, as well as it is obliged to form a national renewable action plan in order for these targets to be achieved.

For the case of Cyprus, the target for the share of renewable energy in the final energy consumption has been set at 13% for 2020[50], while the trajectory specified by Cyprus is presented in Figure 11-31. It must be noticed that the design of the trajectory involves a diversified renewable energy mix, meaning that in case climate change impacts will be observed in a specific renewable power category, the whole renewable power production sector shall not be significantly affected.

Finally, potential impacts on renewable energy potential can be counterbalanced by the promotion of RES in terms of capacity: if the rate of renewable power deployment (measured at kW installed) offsets the reduction of kWh due to reduced RES potential, the yearly total kWh produced by RES will grow over time.

Moreover, an indicative list of measures (administrative and economic) undertaken up to the present for the promotion of renewable energy sources is given below:

Administrative measures

- Establishment of Cyprus institute of energy (2000)
- Establishment of Cyprus Energy Regulator Authority (August 2003)
- Establishment of Cyprus Transmission System Operator (2003)
- Support Scheme Plans (2004-2008 & 2009-2013)
- Establishment of the “Energy office for the citizens of Cyprus” (9/2/2009)
- Adoption of the “One Stop Shop” principle (2002)

Legal measures

[50] Whereas the corresponding share of RES in the electricity production sector is set at 16%

- L. 174/2006: "Promotion of Combined Heat and Power"
- Obligation of the Electricity Authority of Cyprus (EAC) to purchase electricity using RES (2002)
- Licensing exemption (from CERA) for the construction and operation of wind power systems up to 30kW, and photovoltaic systems and biomass systems up to 20 kW

Economic measures

- Special fund for the promotion of RES and energy conservation (August 2003), the revenue of which comes from an additional charge per kWh consumed by all electricity consumers categories (0.0022€/kWh)
- Reduced application fee of very small PV, Wind and Biomass units

Social measures

- Organization of information campaigns, seminars and workshops on renewable power production.

Regarding the economic incentives, it can be said that the subsidy for RES installed at household level is up to 55%, while for larger scale systems there exists a feed-in tariff system 'subsidizing' the price of sold electricity (€/kWh).

Given the wide variety of measures taken for fostering renewable power penetration to the energy production sector, the adaptive capacity is considered to be **Limited to Moderate**.

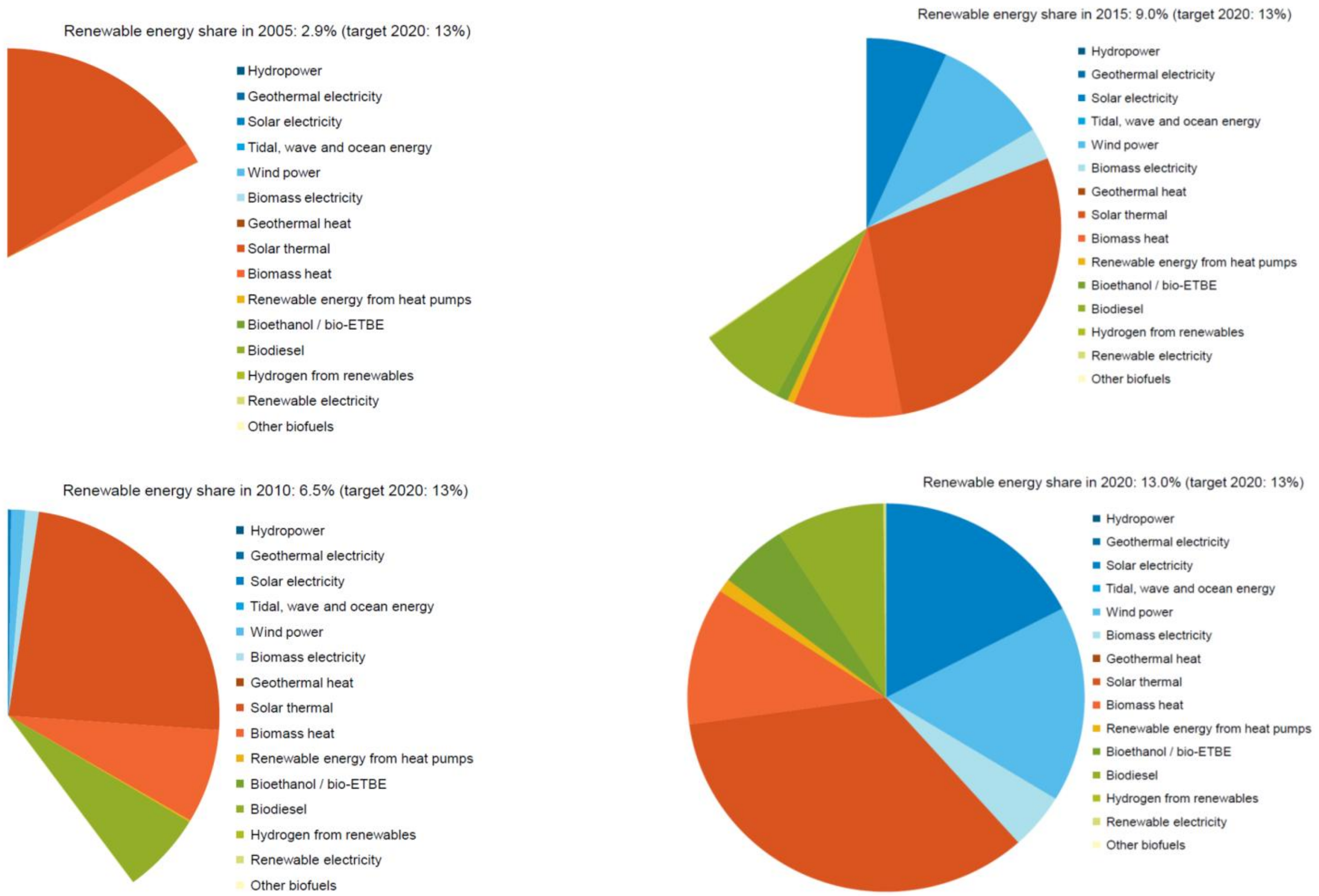


Figure 11-31: Indicative trajectory for the shares of energy from renewable sources in the final energy consumption until 2020

Source: MCIT, 2010

11.4.2 Efficiency of thermal power plants

11.4.2.1 Assessment of sensitivity and exposure

Sensitivity: As discussed in Section 11.3.2, due to temperature increase (air and water) the required condensing power will increase leading to reduced thermal efficiency of power plants.

In order to assess the sensitivity of thermal efficiency of the power plants to climate change the following indicator was used:

- Change of thermal coefficient of efficiency of power plants over time.

In order to obtain a global picture of the impact, the thermal efficiency of each power plant should be monitored and regularly recorded. This has already been realized for the power plants of Cyprus by the Electricity Authority of Cyprus (*EAC*), however no correlation of the decreased efficiency of the units has been attributed to climate change; rather, it is attributed to the ageing of the units.

EAC considers that, in essence, the efficiency has low sensitivity to temperature changes[51]. This is in accordance with studies that have been elaborated on a worldwide basis, which imply a drop in the efficiency in the order of 1% (0.2 - 0.3% has been reported) (**Kirkinen, 2005; UNEP, 1998**). To this end, the sensitivity was ranked as **limited**.

Exposure: The impact (reduction) on the thermal coefficient of efficiency, would affect all three power stations which exist in Cyprus. However, the energy produced and delivered to balance the energy demand would slightly be affected and as a result the exposure is considered as **limited to moderate**.

11.4.2.2 Assessment of adaptive capacity

In order to reduce this impact, more careful design of the thermal power plants can be made, implementing a series of proper modifications in the typical configurations which are used at present, most of which relate to the selection of proper sitting of the units or better operation of the equipment. However, no such measures have been taken in Cyprus for climate change adaptation purposes, nor it is projected to take place in the short-term. To this end, the adaptive capacity is ranked as **limited**.

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11.4.3 Energy demand for heating and cooling

11.4.3.1 Assessment of sensitivity and exposure

Sensitivity: In order to assess the sensitivity of the demand for heating and cooling to temperature increase the following indicators were established:

- **Heating Degree Days (reduction from 1980 to 2004):**
  - Mountainous areas: 327.3 fewer HDD (reduced by 10.3%)
  - Low land areas: 219.2 fewer HDD (reduced by 13.4%)
  - Coastal areas: 257.2 fewer HDD (reduced by 20.4%)
- **Cooling degree days (increase from 1980 to 2004):**
  - Mountainous areas: 11.3 additional CDD (increased by 726.7%)
  - Low land areas: 219.2 additional CDD (increased by 74%)
  - Coastal areas: 257.2 additional CDD (increased by 221.3%)
- **Peak demand (2010): 1,148 MW**
- **Energy use (2010): 2,298 kg oil eq./cap**
- **Maximum output capacity (2010): 1,438 MW**
- **Energy capacity (2010): 5,205 GWh**

The most significant change that is related to climate change is the change (reduction) in heating degree days, which substitutes favorable impact, and the change (increase) in cooling degree days, which substitutes adverse impact. It must be noticed that these changes are related with the temperature increase observed in Cyprus which equals to 0.8^{o}C compared to the temperature levels of the last century (see also Section 11.3.3). It is worth noticing that the increase in cooling degree days is remarkable, especially for mountainous and coastal areas (increased by 726.7% and 221.3% respectively compared to 1980 values).

To this end, the demand for power has been estimated to present **Very High** sensitivity to temperature changes.

Exposure: The energy demand will affect the most important sectors of the Cyprus economy, involving commerce & services and industry, as well as households. More particularly, as presented in Figure 11-3, the contribution by sector in the electricity consumption is as follows:

- Households: 36.33%
- Commerce& Services: 41.64%
- Industry: 17.07%
- Agriculture and fisheries: 3.19%

The increase of the demand for electricity shall affect mainly the tertiary sector which includes households and commerce & service sectors. The aggregate share of these two sectors for Cyprus totals 78%, reflecting that the demand for power is very highly exposed to climate change and in particular temperature increase. What is more, preliminary results from a recent study (Zachariadis, 2010) indicate that the welfare loss associated with the additional electricity requirements can reach 15 million € in 2020 and 45 million € in 2030. The burden induced per household is estimated around 30€/year in 2020 and 80€/year in 2030 (at constant prices of year 2007).

Finally, according to the Meteorological Service of Cyprus, the change in cooling/heating demand will vary across regions, as shown in the following table.

Table 11-7: Observed changes in heating/cooling degree days in Prodromos, Athalassa and Larnaca meteorological stations

	Heating degree days[52]			Cooling degree days[53]		
Meteorological Station[54]	**Prodromos**	**Athalassa**	**Larnaca A/P**	**Prodromos**	**Athalassa**	**Larnaca A/P**
1980	3040.1	1375.2	1213.2	1.5	201.2	49.7
2004	2725.9	1191.1	966.3	12.4	350.0	159.7
Difference *	(314.2)	(184.1)	(246.9)	10.9	148.8	110.0
Mean Value	**(248.4)**			**89.9**		

* Note: Increase (Decrease)

As obvious from the above table:

[52] The linear regression equations used (base temperature=20°C) for heating degree days are the following:

- y=-13.091x+3,040.1 (Prodromos meteorological station) , applied for years 1980-2004;
- y=-8.767x+1,375.2 (Athalassa meteorological station) , applied for years 1983-2004; and
- y=-10.288x+1,213.2 (Larnaca meteorological station) , applied for years 1980-2004;

The regression lines are presented in Section 11.3.3. For obtaining the values of heating or cooling degree days ("Y values") for years 1980 and 2005, the X values range from 0 to 24, corresponding to years 1980 to 2004 respectively.

[53] The linear regression equations used (base temperature=26°C) for cooling degree days are the following:

- y=0.4528x+1.552 (Prodromos meteorological station), applied for years 1980-2004;
- y=7.0845x+201.23 (Athalassa meteorological station) applied for years 1983-2004; and
- y=4.5839x+49.669 (Larnaca meteorological station) applied for years 1980-2004;

The regression lines are presented in Section 11.3.3. For obtaining the values of heating or cooling degree days ("Y values") for years 1980 and 2005, the X values range from 0 to 24, corresponding to years 1980 to 2004 respectively.

[54] With reference to the location of the three Meteorological Stations the following apply:

- Prodromos meteorological station: situated in mountainous area
- Athalassa meteorological station: situated in low-land area
- Larnaca meteorological station: situated in coastal area

- **mountainous areas** present the highest decrease in "heating degree days" and the smallest increase in "cooling degree days";
- **low land areas** present the lowest decrease in "heating degree days" and the highest increase in "cooling degree days"; and
- **coastal areas** present significant decrease in "heating degree days" and more significant increase in "cooling degree days".

Given that Cyprus is characterized by high coastal infrastructure development (see Section 0 "Infrastructure") and that the major part of the capital is situated in the low land climate zone (see Figure 11-32) the exposure of heating/cooling demand has been ranked as **very high**.

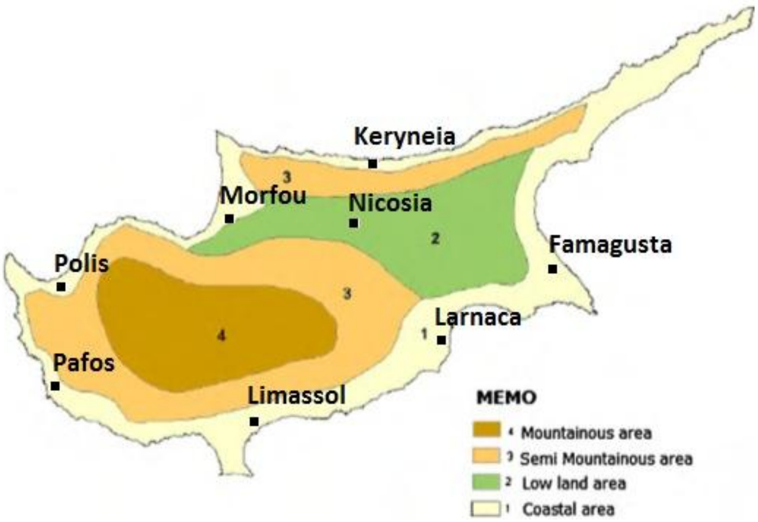

Figure 11-32: Map of Cyprus showing the four major climatic zones

11.4.3.2 Assessment of adaptive capacity

The adaptive capacity of the sector to changing demand in power and heat is dependent on the following four (4) aspects:

- Installation of new power plants for following future energy demand of the island;
- Energy efficiency measures undertaken or underway;
- Use of solar energy for heating and cooling. In Cyprus, solar thermal systems are widely used for the needs for hot water, while photovoltaic systems are increasingly used at household level reducing therefore the pressure on the energy supply sector; and
- Introduction of natural gas in the energy supply portfolio.

New power stations

- **Maximum output capacity (2016):** **~1,700 MW**[55]
- **Peak demand (2016):** **~1,400 MW**[56]
- **Energy capacity (2020):** **7,360 GWh**[57]

In order to assess the sensitivity of the sector regarding the changing demand for electricity and heat a series of additional indicators should be taken into consideration, as for instance energy dependence of the island on imports.

First of all, the main sensitivity lies in the capacity of supplying the ever increasing demand for electricity, which is partly attributed to economic and development factors as well as to climate change (mainly temperature increase).

The projected increase in electricity demand is presented in Figure 11-33.

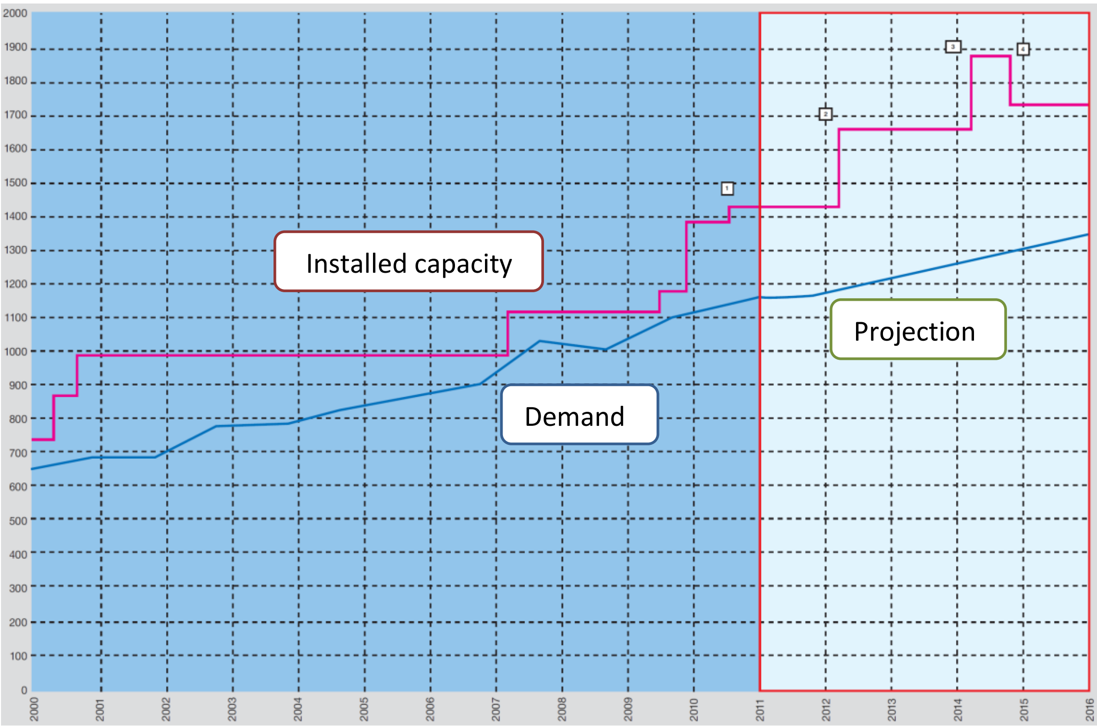

Figure 11-33: Installed capacity and demand: Actual figures and projection

Source: EAC, 2010

As obvious from the above diagram, the electrical requirements are expected to grow over time, fact that requires the installation of new power plants. The EAC's plan for the commissioning of new power plants and the decommissioning of old, existing plants is presented in Figure 11-34.

[55] Source: (EAC, 2011; p. 31)
[56] Source: (EAC, 2011; p. 31)
[57] Source: (EEA, 2011; p. 207)

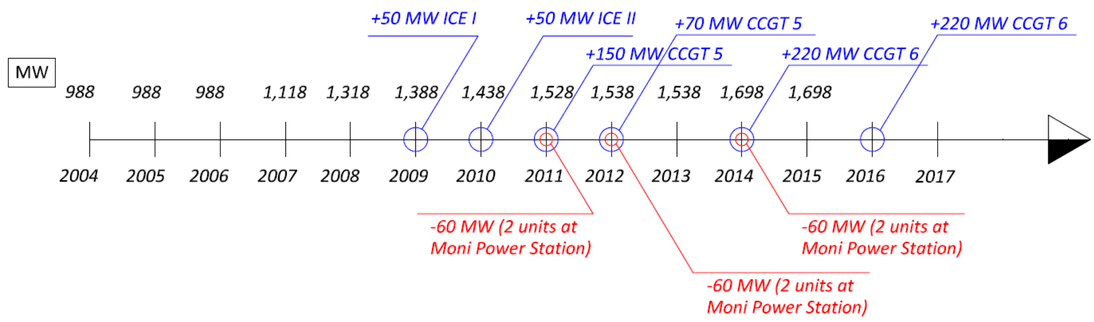

Figure 11-34: Installation of new power plants and decommissioning of existing units until 2017

Source: Own production (NTUA working team)

It must be noticed that, while there exists a sufficient follow-up between supply and demand, meaning that EAC has developed a plan to guarantee the succesfull delivery of power in order to meet the increasing demand (lowering down the sensitivity), there is a sustained challenge which needs to be addressed. The current electricity production regime is dependent on imported oil, fact that implies concern over the energy dependence of the island, which in turn implies questions about how secure is the energy system and capable of delivering electrical energy whatever the external political and economic circumstances.

More specifically, as illustrated in Figure 11-36, the primary energy consumption of Cyprus is dependent highly in petroleum products[58], the cost of which totaled to 3 billion € corresponding to 19.7% of the total cost on imports or 7.3% of the GDP of the Republic of Cyprus. The same does not apply for EU-27 and the globe.

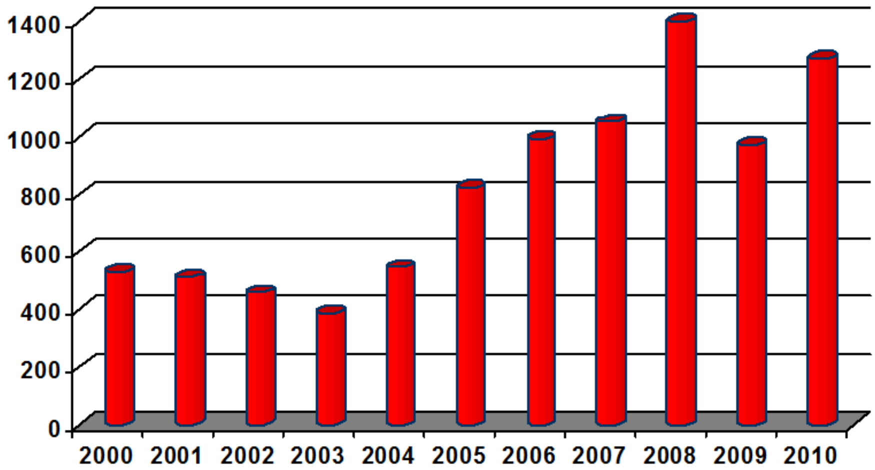

Figure 11-35: Cost of imported fossil fuels in Cyprus for the years 2000-2010

[58] There is a minor contribution of coal and lignite (1%) to the primary energy consumption. The major consumer of this type of energy resource is industry and in particular cement production.

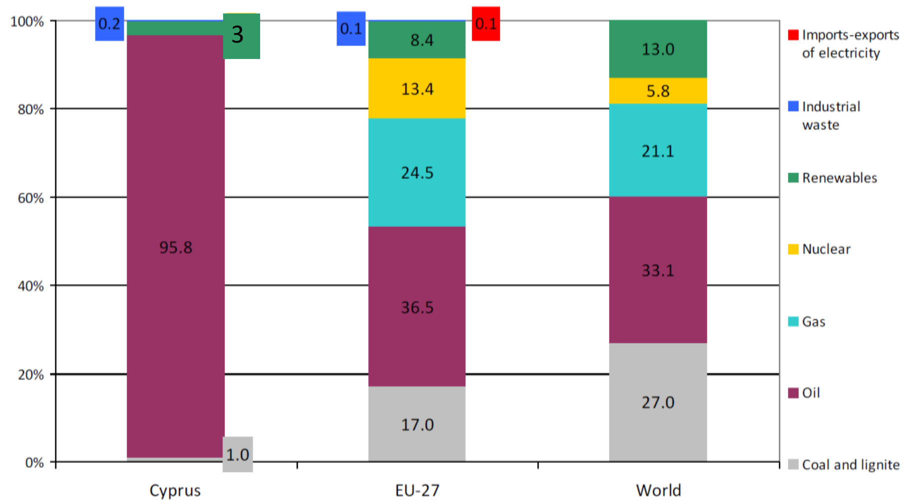

Figure 11-36: Primary energy consumption by fuel for Cyprus, EU-27 and worldwide

Energy efficiency measures

Cyprus has established a National Energy Efficiency Action Plan, which involves the implementation of a set of measures for improving energy efficiency until 2020. The indicative intermediate target for 2016 was set at 185,000 toe[59], while the contribution by sector is as follows (MCIT, 2011):

- Residential sector: 161,877 toe (87.5%);
- Tertiary sector (public sector, general government and enterprises): 23,681 (12.8%);
- Industrial sector: 1,284 toe (0.69%) and
- Transport sector: 3,909 toe (2.11%).

The Republic of Cyprus in compliance with Article 14 of Directive 2006/32/EC of the European Parliament has submitted its 2nd National Energy efficiency Action Plan in 19/07/2011. In this report all energy efficiency measures that have already been implemented or/and are expected to be implemented by 2020, are recorded and analyzed. A comprehensive summary of these measures is given by sector next.

Primary energy savings

- Penetration of natural gas in power generation (combined cycle generation) from 2015 and onwards
- Reduction of transmission and distribution losses (improvement of the power factor of substations, development of new interconnections with increased capacity such as rubus twin type etc.)

[59] Reflecting 10% energy savings comparing to the energy consumption of the reference year.

- Grant scheme for promoting the cogeneration of electricity and heat

End use energy savings

(a) Residential sector (9 measures: 4 implemented, 5 not implemented yet)

1. Energy efficiency of new dwellings (building codes and enforcement), *Implemented*
2. Grants Scheme for energy savings in the residential sector (existing dwellings) 2004-2009 (Grants Scheme for energy savings in the residential sector (existing dwellings)) , *Implemented*
3. Distribution of free compact fluorescent lamps (Budget: € 2,713,138) , *Implemented*
4. Grants scheme to encourage the use of RES in the residential sector, 2004-2010 (Budget: € 14,658,440) , *Implemented*
5. Energy efficiency of dwellings undergoing major renovation (building codes and enforcement) , *Not Implemented yet*
6. Maintenance and inspection of boilers and heating installations (building codes and enforcement) , *Not Implemented yet*
7. Maintenance and inspection of air conditioning systems of an effective rated output of more than 12 kW (building codes and enforcement) , *Not Implemented yet*
8. Grants Scheme for energy savings in the residential sector (existing dwellings) 2011-2020 (Budget: € 52,680,000) , *Not Implemented yet*
9. Grants scheme to encourage the use of RES in the residential sector, 2011-2020, *Not Implemented yet*

(b) Tertiary sector:

1. National action plan for Green Public Procurement, 2007-2009 (Budget: € 24,300 for purchasing fluorescent lamps, € 328,880 for purchasing new air conditioners installed where a new need has come up, € 301,167 for purchasing new air conditioners in replacement of existing ones, € 3,988,321 for purchasing office computers, € 265,226 for purchasing new LCD monitors) , *Implemented*
2. Government grants scheme for energy savings/RES for the public and wider public sector, 2004-2009 (Budget: € 37,908) , *Implemented*
3. Energy efficiency of new buildings in the tertiary sector, *Implemented*
4. Grants Scheme for (end-use) energy savings in the tertiary sector (existing enterprises) 2004-2009 (Budget: € 2,141,440) , *Implemented*
5. Grants scheme to encourage the use of RES (end use) in the tertiary sector, 2004-2010 (Budget: € 1,399,503) , *Implemented*

6. Energy efficiency of tertiary buildings undergoing major renovation, *Not Implemented yet*

7. Maintenance and inspection of boilers and heating installations in the tertiary sector, *Not Implemented yet*

8. Maintenance and inspection of air conditioning systems of an effective rated output of more than 12 kW in the Tertiary Sector, *Not Implemented yet*

9. National action plan for Green Public Procurement, 2010-2020, *Not Implemented yet*

10. Grants Scheme for (end-use) energy savings in the tertiary sector (existing enterprises) 2011-2020 (Budget: € 5,791,464) , *Not Implemented yet*

11. Grants scheme to encourage the use of RES (end use) in the tertiary sector, 2011-2020 (Budget: € 2,600,000) , *Not Implemented yet*

12. Grants Scheme for cogeneration of high efficiency heat and power in the Tertiary Sector, 2011-2020 (Budget: € 7,700,000) , *Not Implemented yet*

13. Action Plans of Municipalities and Communities, 2010-2020, *Not Implemented yet*

(c) <u>Industrial sector</u>

1. Grants Scheme for energy savings (in existing industrial enterprises), 2004-2009 (Budget: € 653,054) , *Implemented*

2. Grants scheme to encourage the use of RES (end use) in the industrial sector and agriculture, 2004-2010 (Budget: € 187,597) , *Implemented*

3. Grants Scheme for energy savings (in existing industrial enterprises), 2011-2020 (Budget: € 2,591,813) , *Not Implemented yet*

4. Grants scheme to encourage the use of RES (end use) in the industrial sector and agriculture, 2011-2020 (Budget: € 424,000) , *Not Implemented yet*

5. Grants Scheme for cogeneration of high efficiency heat and power in the Industrial Sector, 2011-2020 (Budget: € 8,500,000) , *Not Implemented yet*

(d) <u>Transport sector</u>

1. Grants Scheme for energy saving in transport (purchase of hybrid vehicles, electric vehicles and low-emissions vehicles), 2004-2009 (Budget: € 2,596,823) , *Implemented*

2. Scrapping of Vehicles, 2008-2010 (Budget: € 5,785,055) , *Implemented*

3. Scrapping of Vehicles, 2011-2020, *Not Implemented yet*

4. Action plan to strengthen public transport, *Not Implemented yet*

(e) Horizontal measures (*all implemented*)

1. Information campaign on energy saving issues (Budget: € 210,000)
2. Online student training programmes
3. Publishing educational books for students
4. Publishing 2 special information publications for young children
5. Publishing and distributing posters and stickers on energy saving
6. Establishing a student competition for students' projects on RES and ES, with 3 monetary awards (Budget: € 1,700 annually)
7. Lectures on RES and ES at schools
8. Publishing and distributing various information publications and guides on RES and ES investment
9. Energy saving report (Information campaign)
10. Energy Saving Award (Information campaign)
11. Organizing training seminars and day events for citizens and organized groups of people
12. Energy Awareness and reducing energy consumption program in buildings in the Public sector and general government

Natural gas introduction

In order to diversify the energy supply mix, a policy measure which shall be soon undertaken is the introduction of natural gas. By 2014 new gas-fired plants are scheduled to operate. The use of natural gas in power generation is estimated to lead savings of up to 271,000toe (MCIT, 2011).

On the 28th of December 2011 Noble Energy announced the discovery of natural gas at the Cyprus Block 12 prospect, offshore the Republic of Cyprus as a result of the 1st licensing round for hydrocarbon exploration in its EEZ. The Cyprus A-1 well encountered approximately 310 feet of net natural gas pay in multiple high-quality Miocene sand intervals. The discovery well was drilled to a depth of 19,225 feet in water depth of about 5,540 feet. Results from drilling, formation logs and initial evaluation work indicate an estimated gross resource range of 5 to 8 trillion cubic feet (Tcf), with a gross mean of 7 Tcf. The Cyprus Block 12 field covers approximately 40 square miles and will require additional appraisal drilling prior to development.

The discovery of indigenous gas reserves is anticipated to lead to a redesign of the gas sector structure in Cyprus and revisions of policies, political decisions and schedules would have to be done.

Natural gas is estimated to be available in Cyprus' domestic market approximately in 2016.

Since after the discovery of the natural gas field, there have been changes in the policy of the Republic of Cyprus. More particularly, even if it was initially considered to transport the natural gas to the onshore receiver terminal at Vasilikos in liquefied form, it is unclear whether this option comprises an alternative today or not.

The natural gas demand is projected to rise as illustrated in Figure 11-37. It is expected that the introduction of natural gas in the energy mix will provide a diversified, safer energy profile for Cyprus and that will gradually be used in the electricity production, industry and household sector (MANRE, 2010; pp. 41-42), making the energy sector less sensitive to increasing energy demand patterns.

Based on the measures taken so far and those under way, the adaptive capacity of the cooling/heating demand was ranked as **High**.

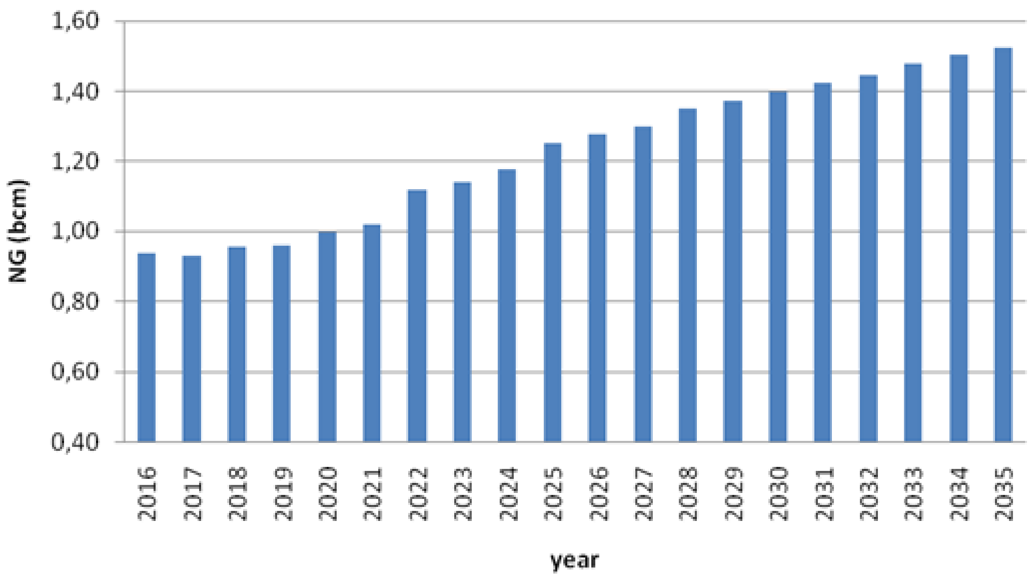

Figure 11-37: Projected natural gas demand between 2016 and 2035

11.4.4 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of the energy sector to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of the energy sector against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

"Impacts" and "Adaptive capacity" should be evaluated on the same scale (1-7). For this to be achieved, the square root of "Sensitivity x Exposure" is used. The results of the vulnerability assessment for the energy sector in Cyprus are summarized in Table 11-8.

Table 11-8: Overall vulnerability assessment of the energy sector in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Renewable energy yield (other than hydropower)	Limited to Moderate (2)	Limited (1)	Limited to Moderate (2)	None (-0.6)
Efficiency of thermal power plants	Limited (1)	Limited to Moderate (2)	Limited (1)	Limited (0.4)
Energy demand for cooling and heating	Very High (7)	Very High (7)	High (5)	Limited to Moderate (2)

As it can be observed from the table above, the energy sector of Cyprus in general is not considered very vulnerable to climate changes. In partiqular, the first vulnerability priority identified for the sector is related to the energy demand for cooling and heating, since it is directly affected by climate changes. However, given that there is potential for increasing energy supply in Cyprus in order to meet the increasing energy demand, the vulnerability towards this impact is characterized as limited to moderate. The second vulnerability priority is related to the efficiency of thermal power plants, which is not expected to be significantly affected by climate changes and thus the vulnerability was ranked as limited. With regard to the impact of climate changes on RES generation, no vulnerability was identified since the only type of RES which is expected to be significantly affected by climate changes is hydropower, which is not exploited in Cyprus due to the already limited water resources, while the impact of climate changes on the other types of RES is minor.

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12 TOURISM

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Abbreviations and Acronyms

CCA	Carrying Capacity Assessment
CTO	Cyprus Tourism Organization
CYSTAT	Cyprus Statistical Service
MAP	Mediterranean Action Plan
SCI	Site of Community Interest
SLR	Sea Level Rise
SPA	Special Protection Areas
SST	Sea Surface Temperature
TCI	Tourism Climatic Index
UNEP	United Nations Environmental Programme

12.1 Climate change and tourism

With its close connections to the environment and climate itself, tourism is considered to be a highly climate-sensitive economic sector. The varied impacts of a changing climate are already becoming evident at destinations around the world and climate change is already influencing decision-making in the tourism sector (Simpson et al., 2008).

Travel decisions are often based on a desire for warm and sunny environments, while winter tourism builds on expectations of snow and snow-covered landscapes. Tourism is thus sensitive to a range of climate variables such as temperature, hours of sunshine, precipitation, humidity, and storm intensity and frequency (Matzarakis and de Frietas, 2001; Matzarakis et al., 2004), along with the consequences that may follow, such as fires, floods, landslides, coastal erosion and disease outbreaks (Wilbanks et al., 2007).

Small island states may find themselves especially vulnerable to changes in the tourism economy because of their often high economic dependence on tourism, concentration of assets and infrastructure in the coastal zone, and often poor resident population (Hay, 2001). Furthermore, tourism businesses, which usually are location-specific, have a lower potential than tourists themselves (who have a wide variety of options) to adapt to climate change (Wall, 1998).

The implications of climate change for any tourism business or destination will also partially depend on the impacts on its competitors. A negative impact in one part of the tourism system may constitute an opportunity elsewhere (Simpson et al., 2008).

12.2 Baseline situation

Tourism is a very important sector of Cyprus economy, attracting millions of tourists every year and providing economic growth and employment for the country. The elements that make tourism in Cyprus stand out over other competing destinations are attributed mainly to its good climate all year round with plenty of sunshine and mild winters, the diversity of tourism product, the sandy beaches, the clean sea as well as the high level of services offered (e.g. telecommunications, banking, health) and infrastructure (e.g. roads).

On average, the overnight stays in Cyprus during the period 2000-2010 consisted of 93% foreign tourists and 7% of Cyprus residents (internal tourism) (CYSTAT, 2011). Regarding the source countries of foreign tourists, arrivals of tourists from the United Kingdom during the period 2000-2010 constituted the main source of foreign tourism with 54% of total tourist arrivals, followed by the Nordic countries with 10%, Germany with 7%, Russia with 6% and Greece with 5% (CTO, 2011a).

It is estimated that approximately 90% of the tourists visits Cyprus for leisure purposes (e.g. sun and sea, sports, culture etc.) while the rest 10% is for business purposes (e.g. conferences, meetings etc.) and for visiting relatives and friends.

12.2.1 Tourist infrastructure

During the last decades, Cyprus has developed its tourist accommodation infrastructure to a great extent in order to meet the needs of the increasing incoming tourism. According to the Cyprus Tourism Organization, in the end of 2010 the tourism accommodation infrastructure in Cyprus consisted of 839 licensed accommodation units, with a total bed capacity of 88,234 beds.

The accommodation units in Cyprus are categorized into seven main types: hotels, hotel apartments, tourist villages, tourist villas, tourist apartments, furnished apartments and guest houses. Hotels and hotel apartments concentrate the biggest share of the total accommodation units established in Cyprus with a share of 27% and 23% respectively. The majority of hotels are 3-star (31%) and 4-star (24%) hotels (CARBONTOUR, 2010).

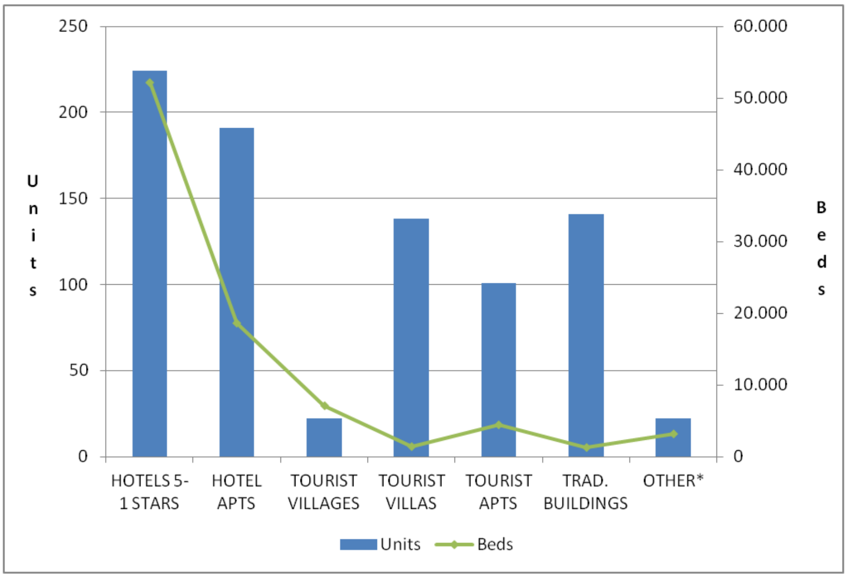


Figure 12-1: Types of tourist accommodation in Cyprus

Source: CARBONTOUR, 2010

95% of beds are established in the coastal cities of Famagusta, Paphos, Larnaca and Limassol, 2.6% in the capital of Nicosia which is located inland and 2.5% in the villages of the mountain Troodos (Hill Resorts). Of all coastal tourism accommodation capacity, 55% is concentrated in the suburban tourism centers around the cities of Limassol, Larnaca and Paphos and about 40% is located in the rapidly growing coastal village communities that have grown into tourism centers. Detailed data regarding the land use planning zones along the coast per district are not available at the moment. It can be estimated however, that islandwide the extent of tourist zones is approximately 103 km of the total coastal length of the Republic of Cyprus (296 km) (Coccossis et al., 2008).

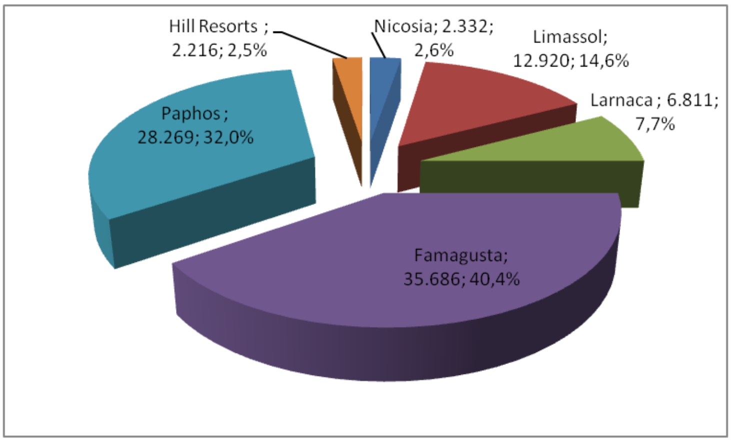


Figure 12-2: Concentration of accommodation beds in the main tourist areas of Cyprus, 2010 (CYPADAPT)

Source: CTO, 2010b

Apart from the tourist accommodation infrastructure, there is a number of other types of tourist infrastructure that is being developed especially during the last decade, in order to diversify the tourist product from the 'Sun and Sea' model.

- Sports tourism infrastructure
    - *Golf tourism*. Within the framework of the New Policy for the Development of Golf Courses, a number of preliminary approvals were granted for new developments. Currently, there are four operating golf courses in Cyprus (CTO).
    - *Sports tourism*. According to a survey on the sports tourism (CTO, 2008), in 2007 the main sports taking place in Cyprus were football (31%), cycling (20%), swimming (15%) and athletics (7%).
    - *Skiing*. Winter ski is practiced in the Troodos Ski Resort of the mountain Troodos.
    - *Diving tourism*. There are 16 diving sites in Cyprus (CTO).

- Nautical tourism infrastructure
    - *Marinas.* Due to the increased demand for berthing spaces and the bright prospects of nautical tourism, the CTO is implementing on a step-by-step basis the masterplan for the development and construction of yacht shelters all along the coastline of Cyprus. So far, one marina in Limassol is under construction, while there are ongoing studies for other two marinas in Larnaca and Aghia Napa.

- Business tourism infrastructure
    - *Conferences and incentives*. There is a great number of conference halls as well as conference rooms offered by hotels in Cyprus.

12.2.2 Spatial distribution of tourism

In 2010, 2,172,998 tourist arrivals were recorded, 89% of which resided in the coastal cities of Cyprus, 5.9% in Nicosia and only 0.2% stayed at the Hill Resorts (Figure 12-3). First in tourist preferences were 3-5 star hotels (46%), followed by A' and B' Class apartments (11%), while 16% of tourists stayed with friends and relatives (Figure 12-4) (CTO, 2010b).

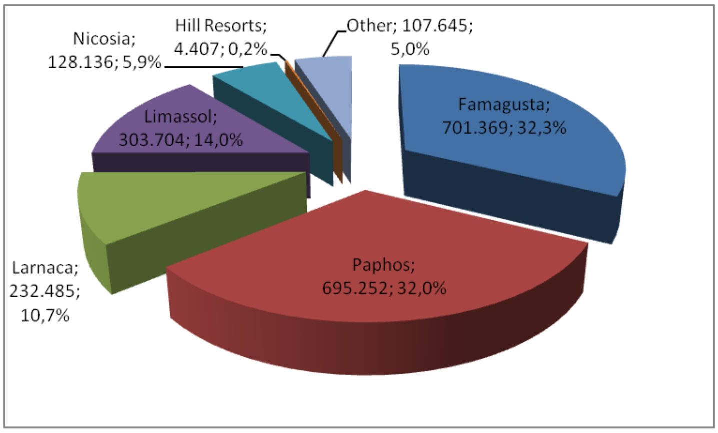


Figure 12-3: Tourist preferences on the location of stay, 2010 (CYPADAPT)

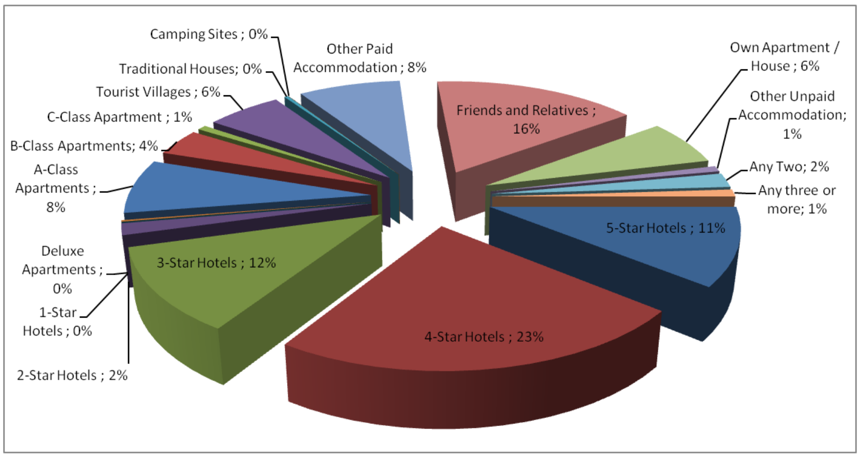


Figure 12-4: Tourist preferences on the type of accommodation, 2010 (CYPADAPT)

According to a specialized study that has been conducted in 2010 in order to promote Conference tourism, Limassol is by far the city that is mostly preferred for Conference tourism (46%). Paphos and Nicosia follow with considerably lower percentages of 30% and 13% respectively. Famagusta and Larnaca gather the lowest scores, 6%, and 5% respectively (CTO, 2011b). Another study on the Sports tourism (CTO, 2010c), showed that the main city for sports tourism was Larnaca (25%), followed by Paphos (24%), Famagusta and Limassol (17% and 18% respectively).

12.2.3 Seasonal distribution of tourism

Tourist arrivals during the year for the period 2001-2010 may be categorized in two seasons. The season from May to October where the share of tourist arrivals is above 11%, with the highest shares of the year recorded in July and August (13-14%), and the season from November to April where the share is below 9%, with the months from December to February reaching the lowest shares throughout the year (2-3%) (Table 12-1).

Table 12-1: Distribution of tourist arrivals during the year (period 2001-2010)

Year	January	February	March	April	May	June	July	August	September	October	November	December
2001	2,38%	3,10%	5,10%	8,80%	12,05%	11,97%	13,85%	13,78%	12,21%	10,00%	3,98%	2,78%
2002	2,24%	2,98%	5,73%	7,46%	11,54%	12,12%	13,54%	12,48%	12,68%	11,41%	4,60%	3,22%
2003	2,58%	3,39%	3,98%	7,38%	10,05%	11,38%	13,81%	14,13%	12,48%	11,81%	5,38%	3,64%
2004	2,40%	3,20%	4,80%	8,10%	11,10%	11,30%	13,00%	13,00%	12,90%	11,90%	4,90%	3,40%
2005	2,40%	2,90%	5,50%	7,40%	11,50%	11,40%	13,70%	13,60%	12,30%	11,80%	4,20%	3,10%
2006	2,30%	2,80%	4,50%	8,60%	11,80%	11,70%	14,20%	13,10%	12,40%	11,80%	4,00%	3,00%
2007	2,10%	2,60%	4,30%	7,80%	11,30%	11,70%	14,60%	14,10%	13,10%	11,40%	3,90%	3,10%
2008	2,10%	2,90%	4,50%	7,60%	11,30%	12,80%	14,30%	13,60%	12,70%	11,10%	4,10%	3,00%
2009	2,20%	2,60%	4,20%	8,50%	11,50%	12,20%	14,20%	13,60%	12,90%	10,80%	4,20%	3,10%
2010	2,10%	2,50%	4,80%	6,40%	11,90%	12,70%	14,10%	14,00%	13,30%	11,10%	4,30%	2,80%

Source: Tourist arrivals 2001-2010, CTO

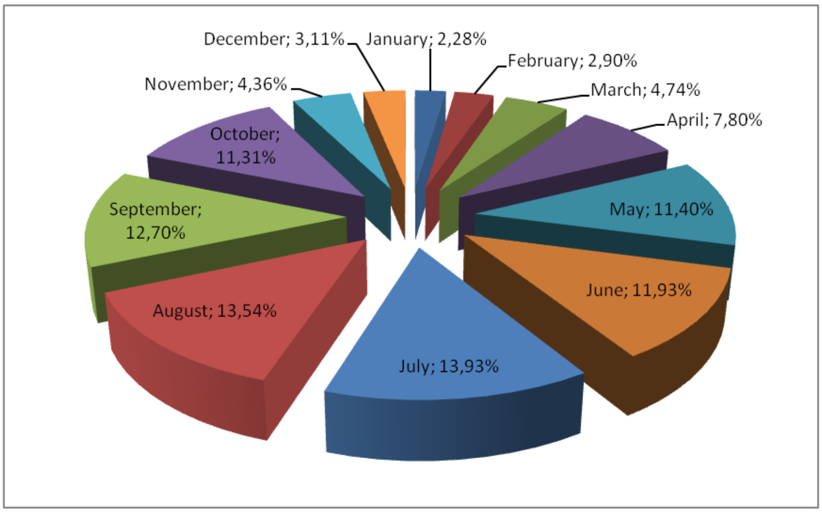


Figure 12-5: Average distribution of tourist arrivals during the year, 2001-2010 (CYPADAPT)

Source: Aggregated data from CTO “Tourist arrivals”

According to the study on Conference tourism (CTO, 2011b) most Conferences took place in March, October and November (13%), followed closely by May (12%), April and June (10% respectively). The highest percentage of sports or training events took place in February (27%) followed by October and March (18% and 15% respectively) (CTO, 2010c). Furthermore, according to data provided from two golf courses operating in Cyprus, 56% and 70% of golfers visit Cyprus during the winter period.

The distribution of tourist arrivals over the four quarters of 2010 was as follows: January-March 9.4%, April-June 31.0%, July-September 41.4% and October-December 18.2%. However, as the different tourist destinations in Cyprus offer different tourist activities (swimming, sports, business etc) which may be exercised in different periods of the year, they present slight deviations from the average seasonality of the country. Intense seasonality is observed in the case of Famagusta, where the majority of tourist arrivals (almost 50%) take place mainly during the period July-September while during the colder months of the year (January-March), the tourist arrivals fall to 3.3%. This phenomenon is also observed in a lesser extent in Paphos, Larnaca and Limassol as well as in the Hill Resorts. On the other hand, Nicosia presents a steady profile throughout the year as the shares of the four quarters of the year are more or less equal.

Table 12-2: Seasonality of tourist destinations in Cyprus during 2010

2010 quarters	Famagusta	Paphos	Larnaca	Limassol	Nicosia	Hill Resorts	Cyprus
Jan - Mar	3.3%	9.3%	14,8%	14.1%	21.2%	17%	9.4%
Apr - Jun	32.6%	31.1%	28.5%	28.8%	28.7%	32.4%	31.0%
Jul - Sep	48.3%	41.4%	37.1%	36.7%	25.4%	31.3%	41.4%
Oct - Dec	15.8%	18.2%	19.6%	20.4%	24.7%	19.3%	18.2%

Source: CTO, 2010b

12.2.4 Tourism revenues

Since the record year 2001 where revenues from tourism reached 2.2 billion euros, tourism receipts have been in decline. In 2010 the total revenues from tourism (including revenues from one-day visitors) were estimated at € 1.57 billion, registering an average annual decrease of 2.6% for the period 2000-2010. It should be emphasized that the impact of financial crisis on the revenues of 2009 was particularly important as the tourism receipts in 2009 were 17% lower compared to revenues from tourism of the previous year.

The significant decline in tourism receipts over the past decade has resulted in the reduction of the dependence of Cyprus economy on tourism. In 2000, the tourism sector accounted for almost 23% of the Gross Domestic Product and 43% of exports of goods and services. The decline in the last decade has significantly reduced the contribution of tourism to the economy resulting in 2009 the tourism accounts to constitute about 10% of GDP and about 21% of exports of goods and services (CTO, 2011a; CYSTAT, 2012).

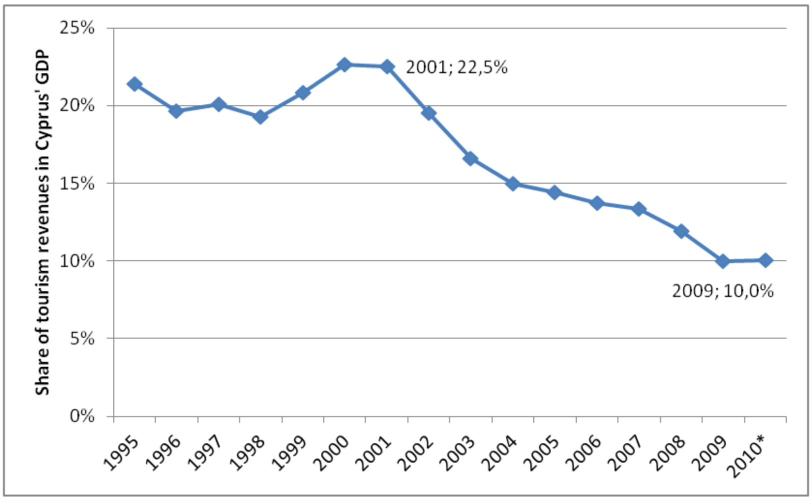


Figure 12-6: Share (%) of tourism revenues in Cyprus Gross Domestic Product (1995-2010) (CYPADAPT) Source: CYSTAT, 2012

12.3 Impact assessment

The climate change impacts on the tourism sector can be divided into two categories; (i) the direct impacts and (ii) the indirect impacts. The first category refers to the impacts on tourism caused directly by climate changes while the second category refers to the impacts caused by climate-induced environmental changes. Following, the observed and expected climate –and climate induced- changes in Cyprus which are associated with the impacts on the tourism sector, are presented.

(1) Increase in air temperature

(2) Decrease in precipitation

(3) Increase in the frequency and intensity of extreme weather events

(4) Sea surface temperature rise

(5) Sea level rise

Next, the current and expected impacts on the tourism sector for the case of Cyprus are presented by impact category.

(i) Direct impacts: Climate changes are expected to alter seasonality in tourism demand and to influence operating costs for a range of activities such as heating-cooling, snowmaking, irrigation and water supply. The increases in the frequency or magnitude of certain weather and climate extremes (e.g. heat waves, droughts, floods) are expected to affect the tourism industry through increased infrastructure damage, additional emergency preparedness requirements and higher operating expenses (e.g. backup water and power systems) (Simpson et al, 2008).

(i) Indirect environmental change impacts: A wide-range of climate-induced environmental changes are expected to influence Cyprus' tourism at the local and regional destination level, such as changes in water availability, biodiversity loss, reduced landscape aesthetic, altered agricultural production (e.g. food and wine tourism), increased natural hazards, coastal erosion and inundation, damage to infrastructure and the increasing incidence of vector-borne diseases (Simpson et al, 2008).

The correlation between the climate changes in climate and the impacts on the tourism sector for the case of Cyprus is presented in Table 12-3.

Table 12-3 : Relationship between observed climate changes and impacts on the tourism sector

Climate changes	Impacts on tourism
Increase in air temperature and decrease in precipitation	– **Warmer summers** : Lengthening of the summer tourist season to autumn and spring, decrease in tourism during the summer season, increase in cooling costs and irrigation needs – **Warmer winters**: Reduced snow cover in ski resorts, shorter winter sports seasons, increased snow-making costs, reduced landscape aesthetics – **Changes in terrestrial biodiversity**: Loss of natural attractions and species, reduced landscape aesthetics and losses in nature-based tourism – **Increase in infectious diseases**
Increase in the frequency and intensity of extreme weather events	– **Heat waves:** Risk for heat stress, higher operating expenses in energy backup systems for increased cooling requirements – **Droughts:** Water shortages, competition over water between tourism and other sectors, additional emergency preparedness requirements in the water sector, limitation to further tourism development (e.g. golf cources), higher operating expenses in water backup systems (desalination plants) – **Storms, waves and floods:** Risk for tourism infrastructure damage, reduced safety of tourists, soil erosion, reduced landscape aesthetics
Climate induced changes	
Sea surface temperature rise	– **Extension of the swimming season** – **Changes in marine biodiversity**: Loss of natural attractions and species, marine resource and aesthetics degradation in dive and snorkel destinations, losses in nature-based tourism
Sea level rise	– **Coastal erosion**: Loss of beach area, reduced landscape aesthetics, higher costs to protect and maintain seafront resorts

The main impacts on the tourism sector presented in the table above are grouped in the following impact categories:

- Warmer summers
- Warmer winters
- Extension of the swimming season
- Heat waves
- Water availability
- Storms, waves and floods
- Increase in infectious diseases
- Biodiversity attractions
- Coastal erosion

Following, the impacts on the tourism sector of Cyprus are further analyzed and assesses on the basis of available data and information.

12.3.1 Warmer summers

Higher summer temperatures, increased humidity and heat waves are expected to lead to a gradual decrease in summer tourism in the Mediterranean and to a shift towards northern destinations due to the increase of tourist discomfort to unpleasant climate conditions. At the same time, an increase in spring and autumn tourist season is expected thus lengthening and flattening tourism season. This could partially offset the losses in tourism during the summer months.

A potential correlation was attempted between the above assumptions and projections for the Mediterranean region with the data available for the case of Cyprus in order to investigate whether this impact is already felt in Cyprus.

Regarding the alterations in tourism seasonality, the data available on seasonal distribution of tourist arrivals to Cyprus for the period 2001-2010, show a small decrease in the winter and spring season with April presenting a significantly higher decrease. The summer season presents a slightly increasing trend in arrivals with June having the higher increase while in autumn higher increases are observed especially in September and October (Figure 12-7).

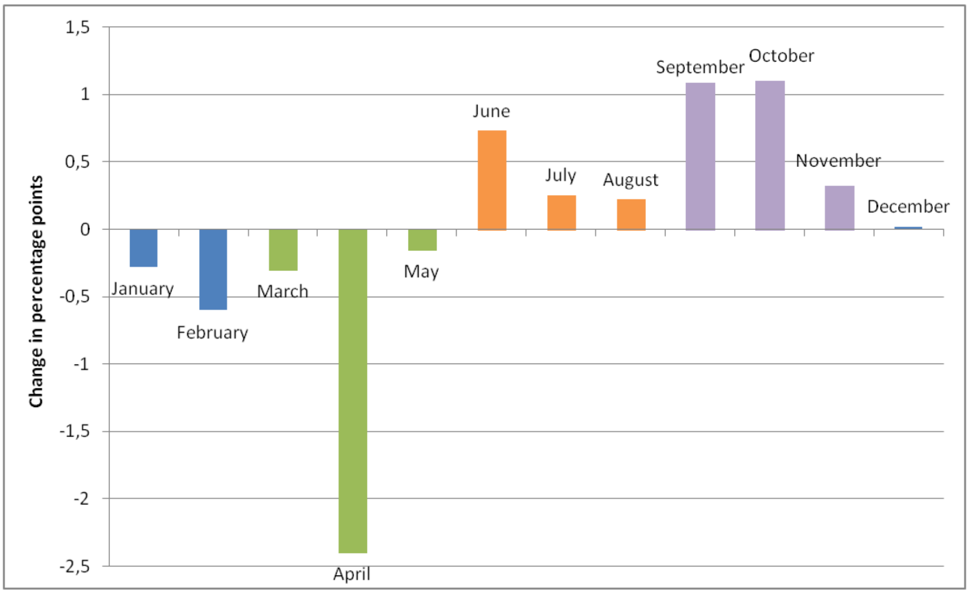


Figure 12-7: Change in the seasonality of tourist arrivals for the period 2001-2010 in percentage points (CYPADAPT)

Source: Cyprus tourism in figures 2001-2010, CTO

The increase of tourist arrivals in the autumn months could indicate that some tourists prefer to visit Cyprus for their summer vacations during autumn in order to avoid the high temperatures and heat waves occurring especially in July and August.

As also shown in Figure 12-5, summer vacations seem to be extended from May to October, thus increasing the length of the summer period to 6 months.

Regarding the expected decrease in tourism, a decreasing trend can be already observed in the tourist arrivals in Cyprus since 2001 (CTO, 2010a), with an average reduction of 2.1%[60] (Figure 12-8), while in the same period both the global and European tourism grew. However, it must be mentioned that this has been attributed so far to other factors, such as the increase of competiveness from neighbor countries, the ageing infrastructure, the fading of local traditions and authenticity etc. (CTO, 2011a).

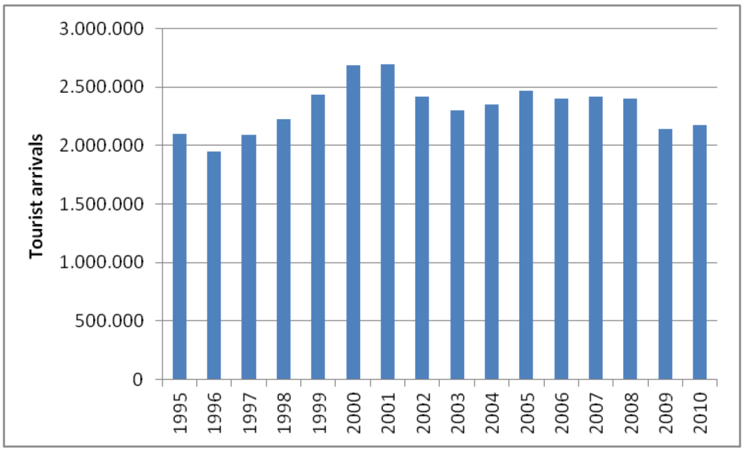


Figure 12-8: Tourist arrivals in Cyprus 1995-2010 (CYPADAPT)

Source: CTO, 2009a; CTO, 2010a

The number of overnight stays during the same period recorded a proportional reduction as well. The reduction in overnight stays had affected each tourist area in different extent. Comparing the figures for 2010 and 2000, the overnight stays in Limassol recorded the greater reduction with 45,3% lesser stays followed by Larnaca with 37%, Paphos with 13.9% and Famagusta with 13,6%. On the other hand, Nicosia recorded an increase in overnight stays of 2,5% (CYSTAT, 2011). The opposite trend observed in the case of Nicosia, could be attributed inter alia to the following factors:

- Nicosia as the capital of Cyprus has a more steady tourism (mainly business) which cannot be easily affected by climate conditions
- Nicosia, unlike the other popular tourist destinations of Cyprus, is not a coastal city and thus do not attract the ‘sun and sea’ tourism segment which is the main tourist product of Cyprus.

[60] It must be mentioned that the global economic crisis had a particularly significant effect on the levels of incoming tourism in Cyprus as the tourist arrivals in 2009 compared to 2008 decreased approximately by 11% while in 2010 the observed increase in relation with the 2009 data was only 1.5%. However, if the effect of 2009 is isolated, the average annual reduction of incoming tourists to Cyprus for the period 2000 to 2008 is limited to 1.4%.

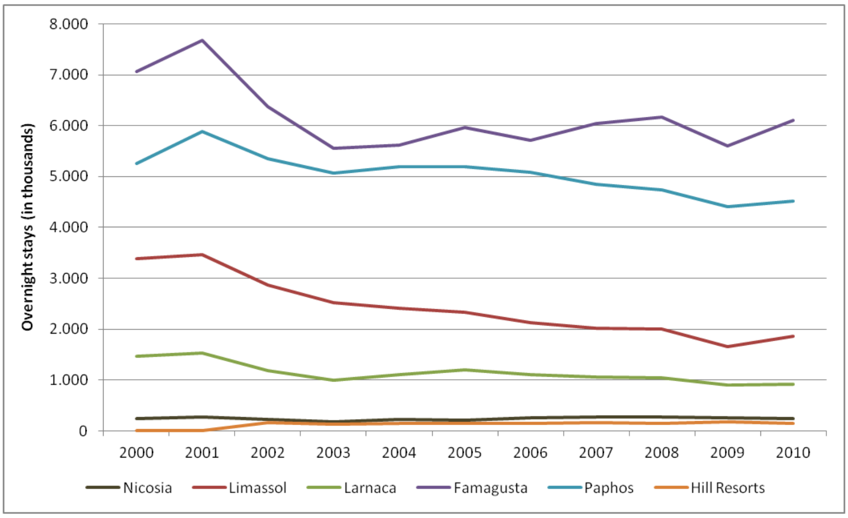


Figure 12-9: Overnight stays in the Cyprus' tourist areas, 2000-2010 (CYPADAPT)

Source: CYSTAT, 2011

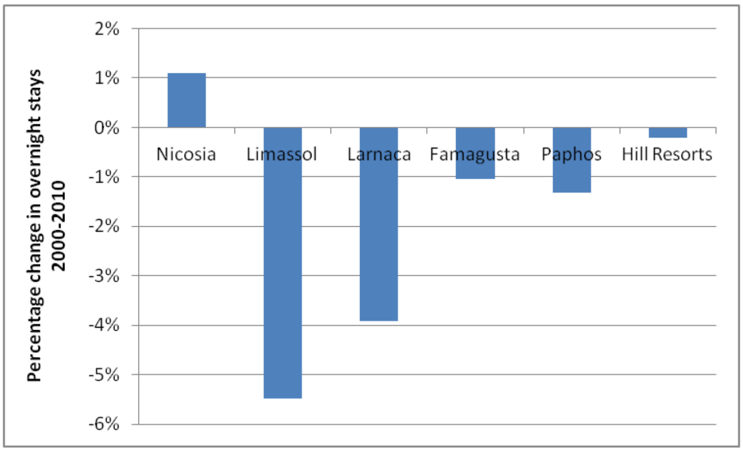


Figure 12-10: Change (%) in the overnight stays in the Cyprus tourist areas, 2000-2010 (CYPADAPT)

Source: CYSTAT, 2011

Another climate change impact on tourism due to higher temperatures is the increased energy consumption for cooling and the subsequent higher costs for hotel owners.

12.3.2 Warmer winters

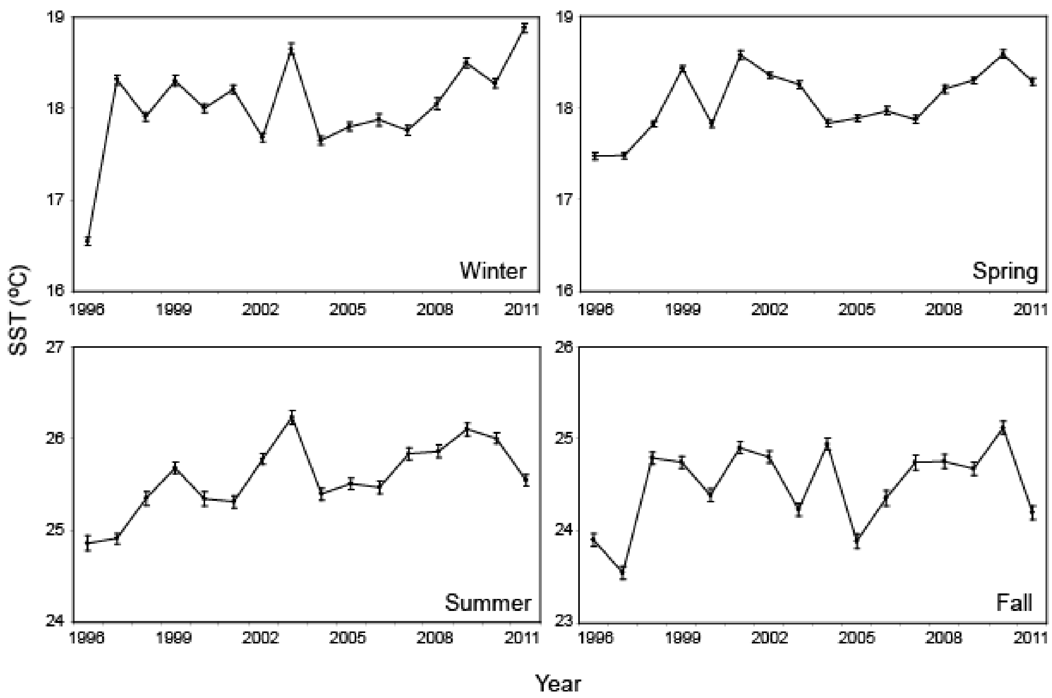
One of the potential impacts of climate change is related to the reduction of the snow-covered area and snow residence time, i.e. the time snow remains before melting. This may shorten the winter sports season, an important tourism attraction during winter. As shown in Figure 12-7, the decreasing trend in tourist arrivals in Cyprus during January and February could be partially attributed to the fact there are less ideal conditions for this kind of vacation. However, There are no reliable and sufficient data available for the case of Cyprus regarding the reduction of snow-covered area, the snow residence time as well as the number of tourists visiting the ski resort of Troodos.

As the share of winter ski tourism in Cyprus is estimated to be very small (mainly internal tourism), it is not considered necessary to conduct further research on the subject.

12.3.3 Extension of the swimming season

Mediterranean Sea Surface Temperature (SST) is expected to gradually increase due to climate change. Higher SST may lead to an extension of the swimming season, during which other water activities are also practiced.

Given that for comfortable water activities SST should be around 20-21°C, current SST during winter and spring, in the Levantine basin where Cyprus is located, is too cold for swimming, while during autumn SST is still suitable for swimming, thus extending the swimming season to 6 months. In Figure 12-11, the mean seasonal SST of the Levantine Basin during the period 1996-2011 is presented.



Seasonal mean values are shown in solid line with points. The annual standard error (s.e.m.) is shown in solid vertical bars.

Figure 12-11: Mean satellite remote sensing sea surface temperatures (SSTs) data from 1996 until 2011

(Source: Samuel-Rhoads et al., 2012)

Tourists in Cyprus are taking advantage of the ideal conditions for swimming prevailing in the beaches of Cyprus during autumn, as it can be seen also from Figure 12-7, where it is shown that the tourist arrivals during autumn in the last ten years have significantly increased.

12.3.4 Heat waves

Like other destinations in the Mediterranean region, Cyprus has been affected by extended heat waves. Heat waves are very likely to affect tourist decisions regarding the travel destination or the length of stay due to tourist discomfort, especially for those population groups that are sensitive to such events (e.g. elderly). The reporting of these events in the media may affect tourist decisions.

In addition, heat waves may affect the tourism sector through increased energy costs for cooling or due to failures in the energy supply network that may cause business interruptions.

No data are available for the case of Cyprus regarding losses for the tourism sector due to heat waves.
It is proposed, that a survey should be conducted on the issue addressing the tourists of Cyprus.

12.3.5 Water availability

Tourism is directly or indirectly dependent on water, whether it is winter tourism, agrotourism, wildlife tourism, golf tourism or 'sun and sea' tourism. If climate change reduces reliability, quantity and quality of available water resources, higher levels of vulnerability are likely to arise, and this will have a significant impact on tourism. Due to the fact that decreased rainfall and extended drought periods in Cyprus, have led the Government to construct a number of desalination plants to secure safe and continuous water supply, the price of water has increased. As a consequence, part of the increased cost for the production of water has shifted to the tourism sector.

Cyprus is characterized as a drought prone area as the country experiences frequent and prolonged drought periods. The water reserves are often limited during the summer periods when the tourism season is at its peak, thus driving up already high local water demand and competition over water between sectors.

The tourism sector in Cyprus, due to the plethora of tourist accommodations as well as due to the fact that about 64% of the tourist accommodations have swimming pools (518 units), is quite water intensive. It was estimated that during 2011, the water demand from the tourist sector constituted 15% of drinking water demand and 4% of total water demand (WDD, 2011 – Annex VII). It must be noted that, it is the water policy of Cyprus that drinking water supply is the last to be affected in Cyprus during drought periods. However, as droughts in the recent past have led to water cuts in drinking water supply, many hotels invested in water saving appliances and practices as well as in water backup systems.

Water scarcity could also affect the sector by substantially limiting its growth and sustainability, as for example in the case of golf tourism. The irrigation of golf courses is regulated through decisions requiring that water supply for irrigation must be made exclusively from recycled water or private production of desalinated water. The capital and operational costs (especially for the desalination plants which are energy intensive) of the water treatment plants are unprofitable or even prohibiting in many cases. In addition, as desalination plants are energy intensive, it was proposed that they should be supplied by private renewable energy plants which require a substantial amount of extra investment cost.

12.3.6 Storms, waves and floods

Storms, waves and floods pose risk for the tourism infrastructure, reduced landscape aesthetics and business interruption costs as well as for the tourists present in such an event. Tourism is more exposed to extreme events than other sectors due to the attractiveness of high-risk areas, as for example coastal tourism is at risk from sea floods, storm surges and waves, etc. In addition, tourists are expected to be at greater risk than residents because they are unfamiliar with the region, the potential hazards and the self-protective behaviour required (Burby and Wagner, 1996). Research has shown that not only tourists but also tourism businesses are usually not well prepared for hazards (Cioccio and Michael, 2007; Hystad and Keller, 2008). Large businesses are generally better prepared than smaller ones (Drabek, 1995).

In Cyprus, no significant floods from the sea or storm surges have been recorded threatening human lives or causing damage to tourism infrastructure. However, it must be mentioned that in 2012, an unprecedented case with high waves in the coasts of Cyprus reaching up to 6 meters height was recorded. As this constitutes an 'one-off' case, no concerns have risen for the safety of Cyprus' coasts and tourism.

12.3.7 Increase in infectious diseases

The increase in vector- borne and water-borne diseases caused by high temperatures, increased extreme weather events and especially flooding could affect the tourism sector by deterring future tourists from visiting the country or by shortening the length of stay of tourists that are already at the island due to sickening or for preventive purposes. Although tourists are especially sensitive to such events,

No statistical data are available for Cyprus regarding tourist behavior during spreding of diseases, since no such event has taken place the last decades.

12.3.8 Biodiversity attractions

Climate change could affect natural ecosystems by worsening their state as a result of changes in temperature and precipitation. The landscape as well as environmental assets and amenities are essential for the development of the nature-based tourism. Loss of natural attractions and species and reduced landscape aesthetics could result in significant reduction of the nature-based tourism. For instance, fires and desiccation in forests constitute an important factor deterring a nature lover from visiting a forest.

Furthermore, the increase of sea surface temperature may have adverse impacts for the marine biodiversity, leading to degradation of marine resources and aesthetics in dive and snorkel destinations and loss of natural attractions and species, thus resulting in losses in nature-based tourism. However, it is not likely that the marine biodiversity of Cyprus will be visibly degraded in the short term from SST rise, as coral reefs that are more sensitive to high temperatures are not present in the Levantine basin.

Given that there are no data available regarding the effect of biodiversity loss on tourist behavior for the case of Cyprus, it is proposed, that a survey on the issue should be conducted addressing the tourists of Cyprus.

12.3.9 Coastal erosion

Countries located on the Mediterranean coast are expected to be affected by sea level rise which could be accelerated by high tides and violent storms. Furthermore, a study shows that a rise in SST induces a likely increase in the frequency and intensity of storms surges and hurricanes (Jäger et al., 2008).

Coastal flooding and inundation due to projected sea level rise combined with potential extreme storm events may cause erosion in the coasts of Cyprus, loss of beach areas, higher costs to protect and maintain waterfronts, loss of vulnerable ecosystems and damage to public beaches. Seaside resorts in Cyprus will also be significantly affected due to their proximity to the shoreline and the violation of the public maritime domain setback for commercial construction in many cases. Sea level rise may also induce implications on natural areas of national interest located in coastal zones.

The impacts of erosion are already apparent in many of the coasts of Cyprus. However, these are not attributed to climatic factors only but also to the exercise of harmful activities on the coasts such as sand and gravel mining, construction of breakwaters for the protection of part of a coast without taking into account the consequences in other parts of the coast, etc.

The impacts from a Sea Level Rise (SLR) in Cyprus are expected to further deteriorate the existing problem of the erosion of Cyprus' coasts. However, it must be noted that SLR is not expected to be significant for the case of Cyprus.

12.4 Vulnerability assessment

In this section, the vulnerability of the tourism sector to climate change impacts is assessed in terms of its sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which tourism is affected by climate changes, exposure is the degree to which tourism is exposed to climate changes and their impacts while the adaptive capacity is defined by the ability of tourism to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The indicators used for the assessment of sensitivity, exposure and adaptive capacity of the tourism sector in Cyprus to climate change impacts are summarized in Table 12-4.

Table 12-4: Indicators used for the vulnerability assessment of climate change impacts on the tourism sector of Cyprus

Vulnerability Variable	Selected Indicators
Warmer summers	
Sensitivity	– Share of arrivals visiting for leisure purposes – Percent of tourists that preferred the coastal cities for their stay
Exposure	– Tourist Discomfort Index per month in the coastal cities – Tourism Climate Index
Adaptive capacity	– Diversification of the tourism product to less-climate dependent and seasonal activities – Expansion of the summer tourist season to less warm months – Use of air-conditioning systems and other relevant appliances
Warmer winters	
Sensitivity	– Share of arrivals during the winter months – Tourists visiting the ski resort of Troodos – The existence of other attractions apart ski during winter
Exposure	– Area of reduced snow-cover (no data) – Reduced snow residence time (no data) – Losses in income (no data) – Number of ski tourism related businesses

Adaptive capacity	– Snow making at the ski resorts – Diversification of the tourism product to less-climate dependent and seasonal activities
Heat waves	
Sensitivity	– Percent of elderly people / tourists visiting Cyprus
Exposure	– Summer months that elderly people visit Cyprus – Frequency and timing of heat waves *
Adaptive capacity	– Use of air-conditioning systems and other relevant appliances
Storms, waves and floods	
Sensitivity	– Share of tourism infrastructure in the coastal areas – Share of tourism infrastructure in the urban centers – Proximity of coastal tourism infrastructure to the coast* –
Exposure	– Frequency of sea floods – Frequency and mean height of waves* – Frequency of storms*
Adaptive capacity	– Construction of coastal defense works
Droughts	
Sensitivity	– Share of water demand from the tourism sector of the domestic water supply – Percent of tourist accommodations having swimming pools – Water intensive tourism businesses
Exposure	– Tourism businesses at risk due to reduced water availability – Increased costs due to the increase in the price of water – Frequency and timing of droughts
Adaptive capacity	– Application of water saving techniques – Reuse water – Production of water (private desalination plants)

Coastal erosion	
Sensitivity	– Concentration of tourism infrastructure and resources to the coastal zone – Dependence of Cyprus' tourism on coastal tourism – Extent of tourist zones of the total coastal length of the Republic of Cyprus
Exposure	– Sea level rise – % of coast already subject to erosion
Adaptive capacity	– Coastal defense works (breakwaters etc) – Beach nourishment works
Biodiversity	
Sensitivity	– Percent of tourism which visits Cyprus for its existing biodiversity
Exposure	– Degree of biodiversity loss in nature tourism attractions *
Adaptive capacity	– Carrying Capacity Assessment – Apply of environmentally sound practices (waste and wastewater management etc)

*There were no data regarding this indicator

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from "none" to "very high".

In the sections that follow, the vulnerability is assessed for the impact categories presented in Section 12.3:

1. Warmer summers
2. Warmer winters
3. Heat waves

4. Water availability
5. Storms, waves and floods
6. Biodiversity attractions
7. Coastal erosion

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability. In case additional data are provided by the competent authorities of Cyprus, the vulnerability of the sector could be re-assessed.

12.4.1 Warmer summers

12.4.1.1 Assessment of sensitivity and exposure

Sensitivity

As an indicator for the dependence on leisure tourism, the share of arrivals visiting Cyprus for leisure purposes was selected. It is assumed that tourists visiting for business purposes or to see friends and relatives are less sensitive to changes in climate (Fagence and Kevan, 1997). According to data from the Statistical Service of Cyprus, the reasons for visiting Cyprus in 2008 were mainly recreational (81,6%) while there is also a small percentage of people (6,9%) who visited Cyprus for professional reasons, i.e. conference, meetings. In addition, as mentioned before, 89% of the tourists visiting Cyprus prefer the coastal cities for their stay. From the above numbers, it can be said that sensitivity of leisure tourism in Cyprus to climate changes is **high to very high**.

Exposure

The exposure indicator for warmer summers should reflect the change in climate from the perspective of leisure tourism. A widely used index that measures the suitability of climate for tourism is the Tourist Discomfort Index, which accounts for the effects of air temperature and relative humidity on the thermal sensation of tourists.

A survey conducted by M. Rutty and D. Scott (2010) among students attending university in five countries of northern Europe (Austria, Germany, Netherlands, Sweden, Switzerland) provided valuable insight for the identification of temperature thresholds at which behavioural response is initiated, regarding tourism destinations in the Mediterranean. The survey sample consisted of 866 respondents. The term "unacceptable" can be interpreted as the threshold to which tourists respond to the climatic stimulus—i.e. the point at which temperatures (climatic stimuli) are "too hot" (threshold) that tourism demand declines (behavioural response).

To calculate the current suitability of thermal conditions in the Mediterranean for tourism based on the stated preference results from the survey, monthly norms for average daytime high temperatures and the average relative humidity (Weather Online, 2009) from the baseline period of 1961 to 1990 were calculated using the humidex formula.

The majority of respondents defined ideal temperatures as between 27°C and 32 °C, with less than 22°C identified as unacceptably cool and greater than 37°C identified as unacceptably hot. Temperatures between ideal and unacceptably cool/hot temperature thresholds represent transition zones. The three temperature classifications have been compared with the monthly average daytime high temperatures (accounting for the effects of relative humidity on thermal sensation) from the baseline period of 1961 to 1990 for five popular Mediterranean beach destinations (Figure 12-12). In Cyprus, ideal temperatures for beach tourism occur during April and May. All five destinations are rated as unacceptably cool during the winter months, with Cyprus and Antalya having the least amount of unacceptably cool months (four). According to the baseline climate, Cyprus is already considered unacceptably hot for beach tourism from June to September, although the majority of arrivals in Cyprus takes place during that period.

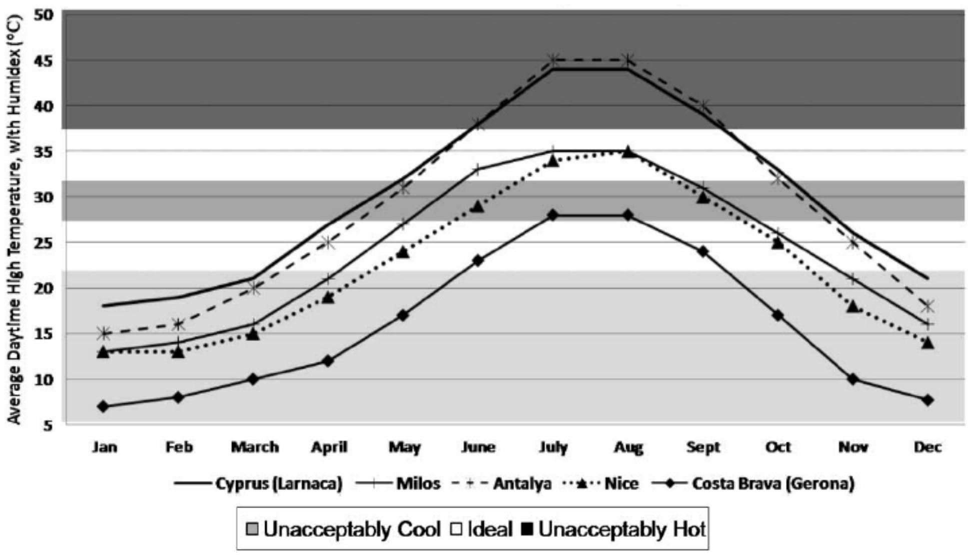
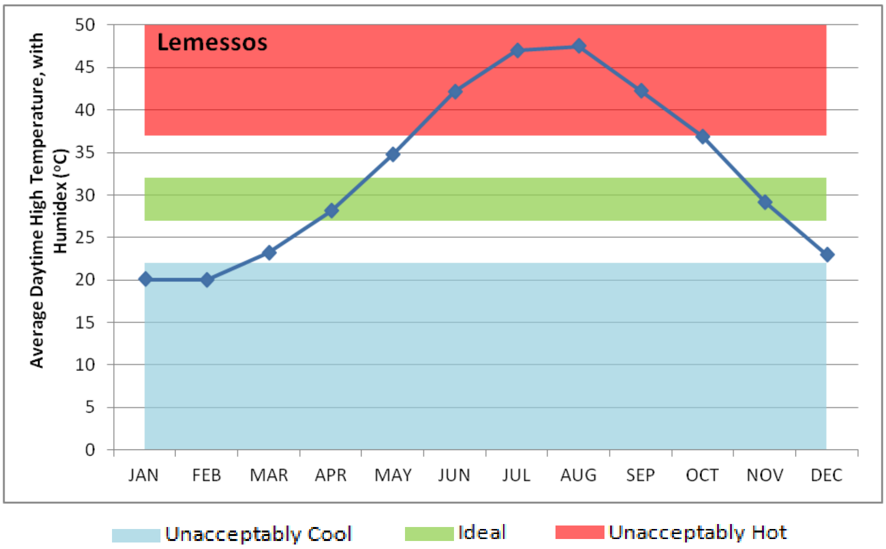
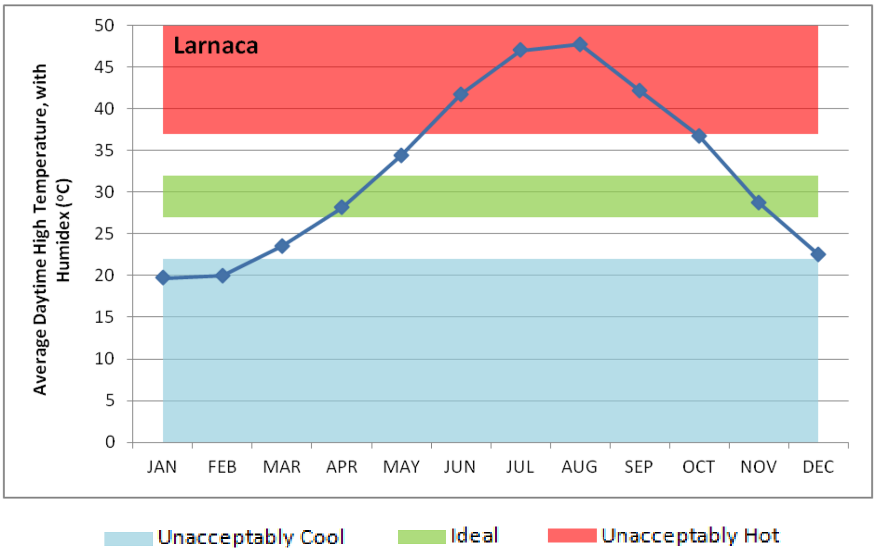


Figure 12-12: Monthly ratings of average daytime high temperature (1961-1990) for beach holiday destinations

Source: M. Rutty and D. Scott, 2010

In the light of more recent data provided by the Meteorological Service of Cyprus[61] for the period 1990-2010, three coastal tourism destinations of Cyprus (Limassol, Larnaca and Paphos) were rated based on the methodology described previously. The results of the ratings (Figure 12-13) show that the period of 'unacceptably hot' months has increased by one month (October) for the case of Larnaca. Limassol presents the same profile with Larnaca while Paphos is more favorably characterized, the 'unacceptably hot' period comprises of the months from June to September.





[61] Contact person: Mr Stellios Pashiardis

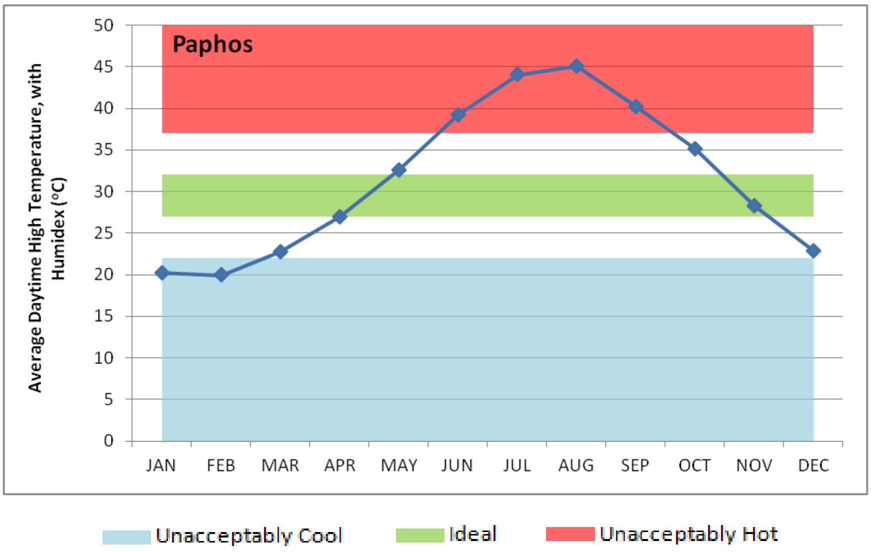


Figure 12-13: Monthly ratings of average daytime high temperature (1990-2010) for three coastal cities of Cyprus (CYPADAPT)

Source: Meteorological Service of Cyprus

Considering the wide distribution of unfavourable climate conditions for beach tourism in terms of both time and geographic distribution, it is considered that the exposure of Cyprus is **high to very high**.

Another widely used index that measures the suitability of climate for tourism is the Tourism Climatic Index (TCI) developed by Mieczkowski (1985). It combines different climatic aspects relevant for tourism: daytime comfort, daily comfort, sunshine, precipitation and wind. Each of these aspects is transformed from its specific unit onto a scale from 0 to 5. The scores are then multiplied by a weighting factor (most weight given to daytime comfort) to produce the index that ranges from 0 to 100.

Table 12-5: Tourism Climate Index and sub-indices (as presented by developed by Mieczkowski)

Rating	Effective temperature (°C)	Mean monthly precipitation (Mm/month)	Mean monthly sunshine (Hours/day)	Wind speed (Km/h)			Wind chill cooling (Watts/m2/hr)
				Normal	Trade wind	Hot climate	
5.0	20 – 27	0.0 – 14.9	>10	<2.88	12.24 – 19.79		
4.5	19 – 20 27 – 28	15.0 – 29.9	9 – 10	2.88 – 5.75			
4.0	18 –19 28 – 29	30.0 – 44.9	8 – 9	5.76 – 9.03	9.04 – 12.23 19.80 – 24.29		<500
3.5	17 – 18 29 – 30	45.0 – 59.9	7 – 8	9.04 – 12.23			
3.0	15 – 17 30 – 31	60.0 – 74.9	6 – 7	12.24 – 19.79	5.76 – 9.03 24.30 – 28.79		500 – 625
2.5	10 – 15 31 – 32	75.0 – 89.9	5 – 6	19.80 – 24.29	2.88 – 5.75		
2.0	5 – 10 32 – 33	105.0 – 104.9	4 – 5	24.30 – 28.79	<2.88 28.80 – 38.52	<2.88	625 – 750
1.5	0 – 5 33 – 34	105.0 – 119.9	3 – 4	28.80 – 38.52		2.88 – 5.75	750 – 875
1.0	-5 – 0 34 – 35	120.0 – 134.9	2 – 3			5.76 – 9.03	875 – 1000
0.5	35 – 36	135.0 – 149.9	1 – 2			9.04 – 12.23	1000 – 1125
0.25							1125 – 1250
0.0	-10 – -5	>150.0	<1	>38.52	>38.52	>12.24	>1250
-1.0	-15 – -10						
-2.0	-20 – -15						
-3.0	<-20						

By combining all sub-indices the overall TCI is then calculated:

TCI = 2 (4 CID + CIA + 2R + 2S + W), where

CID is the daytime comfort index (composed of maximum daily temperature and minimum daily relative humidity)
CIA is the daily comfort index (composed of mean daily temperature and daily relative humidity)
R is the precipitation in mm of rain
S is the daily hours of sunshine and,
W is the wind speed in m/s or km/h

Unfortunately, there are not sufficient data at the moment to calculate the TCI score for the case of Cyprus. Instead, the results of Savine (2008) are presented, who calculated the TCI score for beach tourism in the Mediterranean. The optimum effective temperature of 20 and 27 °C was shifted to 27 - 32°C, as it best reflects beach visitor preferences reported by *Rutty and Scott, 2010*.

As all sub-indices have a maximum score of 5, this aggregation leads to an overall maximum score of 100, with acceptable scores lying above 40, good scores above 60 and excellent scores above 80. As it can be seen from Figure 12-14, for the period 1961-1990 the Mediterranean presents good TCI scores from April to October while for the rest of the months are characterized by acceptable TCI.

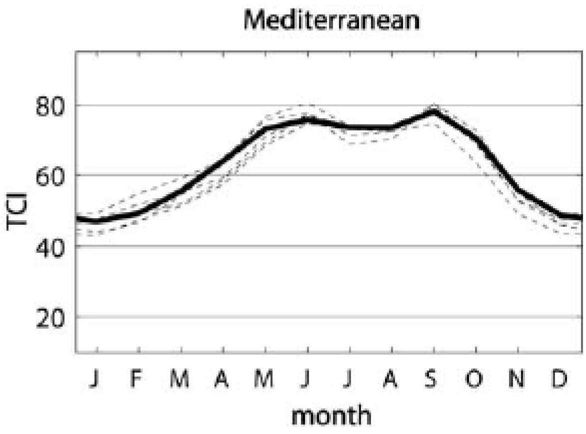


Figure 12-14: Annual cycle of the Tourism Climate Index in the Mediterranean (1961-1990)

Source: Sabine, 2008

In Figure 12-15, the TCI for the summer months (June, July, August) in Europe, which was calculated in the framework of the PESETA project, is presented. As it can be seen, the western part of Cyprus for these months has been characterized as excellent and the central part as very good.

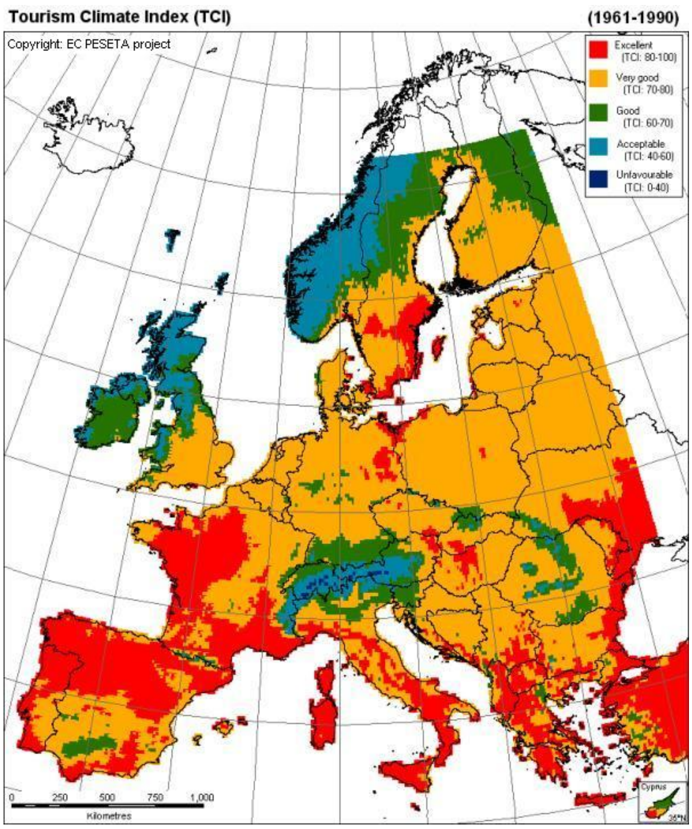


Figure 12-15: Simulated Conditions for Summer Tourism in Europe for 1961-1990

Source: EC/JRC, 2007

However, the two aforementioned TCI case studies (Mediterranean, Europe) refer to a past period (1961-1990).

The data must be reassessed for the current period in order to estimate the exposure of tourism in Cyprus to warmer summers.

12.4.1.2 Assessment of adaptive capacity

In the Mediterranean region, the likely reduction of tourism during the hotter summer months may be compensated for by promoting changes in the temporal pattern of seaside tourism, for example by promoting tourism during the cooler months of the year (Amelung and Viner, 2006) and by diversifying the tourism product to less-climate dependent and seasonal activities (e.g. trekking, hiking, mountain biking, spas, ecotourism etc.) (Scott et al., 2008).

It must be mentioned that the Cyprus Tourism Organization (CTO) has undertaken initiatives towards the diversification of Cyprus' tourist product as it can be seen from its Strategy Plans for tourism, by promoting additional tourist products apart from the 'Sun and Sea' product, such as conference tourism, sport tourism, cycling, golf, weddings and honeymoon trips, hiking, religious and cultural tourism, health tourism (medical and wellness), rural tourism, training and educational tourism, cruising, gastronomic and wine tourism.

In Cyprus, the summer tourist season has already been expanded from the hot months of July and August to May-October, thus partially compensating for possible losses during the hot months. On the other hand, the fact that the total tourist arrivals have decreased during the last ten years may be partially attributed[62] to insufficient adaptive capacity of tourism to hot summers.

Another "common practice" that could provide relief to tourists from the discomfort caused by heat waves while they are inside closed tourist areas, is the use of air conditioning systems or other relevant appliances.

The adaptive capacity of Cyprus' tourism sector to warmer summers is considered to be **moderate**.

12.4.2 Warmer winters

[62] A number of other reasons such as the increase in the price of airline fares is estimated that contributed to decreasing tourist arrivals in Cyprus

12.4.2.1 Assessment of sensitivity and exposure

Sensitivity

For the assessment of sensitivity of winter tourism to warmer winters, two factors were used as indicators, namely: (i) the dependence of tourism on winter months and (ii) the existence of other attractions during winter. Winter months concentrate only 8,3% (see Figure 12-5) of the total arrivals throughout the year in Cyprus. In addition, the tourists visiting the ski resort of Troodos, are mainly residents of Cyprus which constitute approximate 10% of the total tourist arrivals. Regarding the second indicator, a large percent of winter tourist arrivals is linked to professional tourism (which is not sensitive to climate) and a smaller percent is linked to nature based tourism (besides skiing).

It must be also noted that, warmer winters are expected to act beneficially towards winter tourism, as the climate during that period will be more ideal for sightseeing. Considering the above, winter tourism is characterized by **limited** sensitivity to warmer climate.

Exposure

The exposure of winter tourism and especially ski tourism at warmer climate can be expressed in terms of magnitude, as (i) the area of reduced snow-cover, (ii) the reduced snow residence time which can also be translated to losses in income during that period and (iii) the number of ski tourism related businesses (ski resort and tourist accommodations nearby). Given that there are no sufficient data for the quantification of the first two indicators, while as far as the third indicator is concerned, there is only one ski resort in Cyprus and two tourist accommodations operating nearby, the exposure of ski tourism in warmer winters is considered **limited.**

12.4.2.2 Assessment of adaptive capacity

Regarding winter ski tourism, compensating for reduced snowfall by artificial snowmaking is already common practice for coping with year-to-year snow pack variability. However, this adaptation strategy is likely to be economic only in the short term, or in the case of very high elevation resorts in mountain regions and, may be ecologically undesirable. New leisure industries, such as grass skiing or hiking could compensate for any income decrease experienced by the ski industry due to snow deterioration (Fukushima et al., 2002).

For the case of Cyprus, although the winter ski tourism is limited, relative adaptation measures have been undertaken. More specific, a snow making machinery is already installed in the Troodos Ski Club from 2003, thus increasing the adaptive capacity of ski tourism in Cyprus.

In addition, the fact that winter tourism is already diversified by a number of other tourism segments such as conference tourism (majority of winter tourism), sports tourism, cycling tourism, golf tourism etc., and the fact that warmer winters will act beneficially towards winter tourism, the adaptive capacity of Cyprus' winter tourism to warmer winters is considered to be **moderate to high**.

12.4.3 Heat waves

12.4.3.1 Assessment of sensitivity and exposure

Sensitivity

As heat waves occur during the summer seasons, where the temperatures and relative humidity are high and the tourism season is high as well, an increasing risk for heat stress exists. Tourists may be particularly affected by heat waves, as according to the climate of their country of origin, they may not be used to such kind of phenomena and may not know how to protect from such events. Even if this is not the case, heat waves will cause tourists visiting Cyprus in the hot summer months to feel uncomfortable, which may result in shortening the duration of their stay or deciding not to visit this country again. All age groups are considered sensitive to heat waves while the most sensitive age group is the elderly. This group corresponds to approximately 33% (average 1999-2011) of the total tourism in Cyprus (CYSTAT, 2011). Therefore, it is considered that Cyprus' tourism has a **high to very high** sensitivity to heat waves.

Exposure

Given that elderly people (such as pensioners) prefer to travel in Cyprus during the autumn and spring when there are no heat waves, it is considered that the exposure of Cyprus' tourism to heat waves is considered to be **moderate to high**.

12.4.3.2 Assessment of adaptive capacity

The adaptation measures of the tourism sector against heat waves is actually restricted to relieving heat discomfort of tourists while they are inside closed tourist areas with the provision of cool air through air conditioning systems or other relevant appliances. According to the CARBONTOUR (2010) database of the tourist accommodation in Cyprus, 89% of the tourist accommodations have air conditioning systems. However, while tourists are in open areas the only measure that the tourism sector can take to protect them is to provide advises for staying in shady places etc. Therefore, the adaptive capacity of Cyprus' tourism to heat waves is considered to be **moderate**.

12.4.4 Water availability

12.4.4.1 Assessment of sensitivity and exposure

Sensitivity

According to the Water Policy of Cyprus (WDD, 2011), the water demand from the tourism sector is estimated to be 15% of the domestic water supply or 4% of the total water demand. An assessment study of the Cyprus' water resources and water demand in 2000 indicated that daily water use per tourist in Cyprus is more than double in comparison with the water consumption of local residents. Consumption varies of course depending on the type of lodging and facilities offered such as swimming pools and golf courses. The CARBONTOUR (2010) database of the tourist accommodation in Cyprus shows that 64% of the tourist accommodations have swimming pools. In addition, the upgrading of the tourism product of Cyprus is based inter alia to the development of golf courses which require substantial amounts of water for their irrigation. To sum up, the fact that the majority of tourism businesses in Cyprus depend strongly on water availability, makes the tourism sector **high to very high** sensitive to droughts.

Exposure

Given that water supply to the tourism sector is not likely to be restricted, as constant drinking water supply is secured through the increased capacity of the desalination plants according to the new water policy of Cyprus (2011), the tourism businesses exposed to droughts are those that maintain large irrigated areas, such as golf courses. However, the tourism sector is already paying higher amounts for the water that it consumes, as the water price has increased due to the increase in the cost for its production (construction and operation of desalination plants).

It must also be mentioned that the Ministerial Decision of 2005 foresees the own water production for the irrigation of golf courses, which may pose at risk the economic viability of golf businesses due to the high operational costs, especially for the production of water from desalination plants. It can be concluded that the exposure of Cyprus' tourism to droughts is considered **high**.

12.4.4.2 Assessment of adaptive capacity

The Cyprus tourism sector must implement water conservation techniques, such as rainwater storage, use of water-saving devices, desalination or wastewater recycling. Some of the measures have already been implemented by tourist accommodations and especially large size hotels while some measures are not economic for everyone. For these reasons, Cyprus' tourism current adaptive capacity to droughts is considered as **moderate**.

12.4.5 Storms, waves and floods

12.4.5.1 Assessment of sensitivity and exposure

Sensitivity

The coastal tourism infrastructure is especially sensitive to damages from sea floods and storm surges. The percent of tourism infrastructure in Cyprus that is located at the coastal areas of the island is 95%. Therefore, it is considered that Cyprus' tourism has **high to very** sensitivity to storms, waves and floods.

Exposure

According to the records on the flooding events that have been recorded in the period 1859-2011 in Cyprus, none of them has been classified as a sea flood (Water Development Department, 2011). The main type of floods in Cyprus is the urban floods. Therefore, tourism coastal infrastructure is not exposed to floods. On the other hand, storm surges and waves are a more common phenomenon, although in most cases their magnitude is such that they do not have destructive effects for the infrastructure located nearby. Taking into consideration the above, it is considered that Cyprus' tourism has **moderate** exposure to storms, waves and floods so far.

12.4.5.2 Assessment of adaptive capacity

The measures that have been undertaken in Cyprus and which are considered that are also contributing the protection of coastal infrastructure are associated with the construction of coastal defense works. Such works have begun to be constructed in Cyprus since 1980, either by the Government competent services or by tourist accommodation owners. In total, approximately 80 breakwaters, 15 groynes (mostly illegal) and 4 coastal road revetments have been built in several coasts of Cyprus up to now[63]. Given that where these structures have been built, the coastal infrastructure has been significantly protected from storms and floods. Given that there are no risks related to storms and floods, Cyprus' tourism current adaptive capacity is considered **moderate to high**.

[63] Unpublished information provided by the Department of Public Works (person contacted: Mrs Stavrini Theodosiou)

12.4.6 Biodiversity attractions

12.4.6.1 Assessment of sensitivity and exposure

Sensitivity

For the assessment of tourism sensitivity to losses in biodiversity, the percentage of tourism which visits Cyprus for its existing biodiversity may be used as an indicator. In absence of relative data, it is assumed that the percentage of nature based tourism is very little compared to beach tourism in Cyprus which constitute 90% of total tourism, thus **limited** sensitivity is attributed to biodiversity losses for the tourism sector.

Exposure

Reduced soil moisture, increased sensitivity in desertification, more frequent and larger forest fires and increased sea surface temperatures lead to terrestrial and marine biodiversity loss and subsequently to loss of natural attractions for tourism. Although there are not sufficient data for estimating the degree of biodiversity loss (magnitude), based on the fact that the natural tourist attractions constitute a small minority of the tourist attractions in Cyprus (the majority being beaches) no significant losses in overall losses in tourism business are expected. For that reason, the Cyprus' tourism sector is considered to have **limited to moderate** exposure to biodiversity loss.

12.4.6.2 Assessment of adaptive capacity

The tourism sector (tourism accommodation owners, managers as well as the CTO) may implement several adaptation measures in order to increase its adaptive capacity to biodiversity loss, such as to promote the application of integrated tourism Carrying Capacity Assessment (CCA) techniques (considering physical, economic, environmental, socio-cultural and managerial aspects) in protected areas as a tool for tourism development planning, to promote the implementation of Environmental Impact Assessments in environmentally sensitive areas as well as to comply with the national laws for the protection of foreshore zone and of the protected nature areas (SPA, SCI, national forest parks, marine protected areas, fishing shelters).

The CTO has promoted the application of Carrying Capacity Assessments [64] (CCA) for the Hill resorts of Cyprus and has integrated its results into the Regional Tourism Strategy for the Hill Resorts. Another carrying capacity assessment has been made for the case of Larnaca,

[64] The maximum number of people that may visit a tourist destination at the same time, without causing destruction of the physical, economic, socio-cultural environment and an unacceptable decrease in the quality of visitors' satisfaction (World Tourism Organization)

which constituted a pilot study under the framework of the Project CAMP-Cyprus promoted within the wider activities of the Mediterranean Action Plan of the United Nations Environmental Programme (MAP-UNEP). However, CCAs should be applied for all the tourism centers of Cyprus and their results should be binding for the tourism sector.

Although there is a variety of measures and tools for the protection of nature-based tourist attractions, they are not implemented at the degree required due to conflicting interests for the development of beach attractions.

Thus, the current adaptive capacity of Cyprus' tourism to biodiversity loss is estimated to be **limited to moderate**.

12.4.7 Coastal erosion

12.4.7.1 Assessment of sensitivity and exposure

Sensitivity

In order to assess the sensitivity of the tourism sector in Cyprus to coastal erosion, the concentration of tourism infrastructure and resources to the coastal zone as well as the dependence of Cyprus' tourism on coastal tourism were used as indicators.

Approximately 95% of all licensed tourism hotel accommodation capacity in Cyprus is located on the coast. Of all coastal tourism accommodation capacity, 55% is concentrated in the suburban tourism centers around the cities of Limassol, Larnaca and Paphos and about 40% is located in the rapidly growing coastal village communities that have grown into tourism centers. Detailed data regarding the land use planning zones along the coast per district are not available at the moment. It can be estimated however, that islandwide the extent of tourist zones is approximately 103 km of the total coastal length of the Republic of Cyprus (296 km) (Coccossis et al., 2008).

Considering the above, the sensitivity of Cyprus' tourism to coastal erosion is estimated to be **high to very high**.

Exposure

Based on archaeological data, Cyprus appears to be experiencing long-term uplift of between 0 and 1 mm year. This uplift will counteract global sea-level rise and given a global rise in sea level of 0.5 m by 2100, relative sea-level rise in Cyprus will be in the range 0.4-0.5 m (Nicholls and Hoozemans, 1996). Low lying areas, such as Larnaca, may be particularly vulnerable to a sea level rise. For the time being, it is estimated that approximately 38% of the coastal zone of Cyprus has been affected by erosion (Research Promotion Foundation, 2006), but not necessarily the tourist areas. Therefore, Cyprus' tourism exposure to coastal erosion is considered to be **moderate**.

12.4.7.2 Assessment of adaptive capacity

Regarding coastal tourism, the protection of resorts from sea-level rise may be feasible by constructing barriers or by moving tourism infrastructure further back from the coast (Pinnegar et al., 2006).

To deal with issue of coastal erosion, the Government of Cyprus assigned in 1992 the implementation of a project entitled 'Coastal Protection Management for Cyprus' (1993-1996). The project was carried out by the Coastal Section of the Department of Public Works (DPW) of the Ministry of Communications and Works, and Delft Hydraulics with the objective to identify proper protection methods and improve the quality of beaches without causing serious impacts on the environment. The entire coastline of the Republic of Cyprus was divided in twelve 'sections' or coastal areas based on their morphology. Master Plans, as well as conceptual and detailed designs, were developed for three of the twelve coastal areas (Limassol, Larnaca and Paphos South).

In 1998 the Cyprus government started with the implementation of these Master Plans. Another project also initiated in 2000, for the protection of three (3) new coastal areas in Paphos (Kato Pyrgos Tillirias, Crysochou Bay and Zygi-Kiti). The following years, Cyprus has prepared and implemented a number of additional Master Plans and intends to do the same for the rest of the coastal areas that is deemed necessary (Coccossis et al, 2008).

However, many times tourism activities hinder the protection from coastal erosion either by building illegal breakwaters which may have adverse effects to the coast, or by building illegally on the coast.

Therefore, it is considered that Cyprus' tourism has **moderate** adaptive capacity to coastal erosion.

12.4.8 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of tourism to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of the tourism sector against a climatic change impact the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for the tourism sector in Cyprus are summarized in Table 12-6.

Table 12-6: Overall vulnerability assessment of the tourism sector in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Warmer summers	High to Very high (6)	High to Very high (6)	Moderate (3)	Moderate (3)
Warmer winters	Limited (1)	Limited (1)	Moderate to High (4)	None (-3)
Heat waves	High to Very high (6)	Moderate to High (4)	Moderate (3)	Limited to Moderate (1.9)
Water availability	High (5)	High (5)	Moderate (3)	Limited to Moderate (2)
Storms, waves and floods	High to Very high (6)	Moderate (3)	Moderate to High (4)	Limited (0.2)
Biodiversity attractions	Limited (1)	Limited to Moderate (2)	Limited to Moderate (2)	None (-0.6)
Coastal erosion	High to Very high (6)	Moderate (3)	Moderate (3)	Limited to Moderate (1.2)

As it can be seen from the table above, the first vulnerability priority of the sector to climate changes is related to the warmer summers which are responsible for the increase in the level of uncomfortability of tourists visiting Cyprus during summer. However, the adaptive capacity for lengthening the tourist summer season reduces the vulnerability of tourism towards this impact. The decrease in water availability for meeting the needs of the tourism sector constitutes the second priority of the sector, considering that the available water resources are significantly reduced especially during summer when the majority of tourists visits Cyprus and that a significant part of the tourism industry is based on water use. The vulnerability towards this impact is reduced due to the adaptive capacity of Cyprus for increasing water supply mainly with the use of desalination plants. The third place is occupied by heat waves and coastal erosion. Heat waves are a common phenomenon in Cyprus during summer when the majority of tourists visits Cyprus. However, the impact on tourism is not so intense considering that the most sensitive population groups to heat waves, i.e. the elderly people, prefer to take their holidays during the cooler seasons of the year. The adaptive capacity of the sector towards this impact is restricted mainly indoors by providing a cool environment for relieving heat discomfort. The erosion of Cyprus' coasts has a significant impact on tourism since the majority of tourism infrastructure is located at the coasts. Nevertheless, the coastal protection works which have taken place have alleviated the problem in a great extent. Finally, storms waves and floods constitute the last vulnerability priority for the tourism of Cyprus regarding climate changes. However, due to the fact that sea floods, which constitute the majot threat for tourism infrastructure, are not so common in Cyprus, the vulnerability of this impact was considered low.

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13 INFRASTRUCTURE

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Abbreviations and Acronyms

ICT	Information and Communications Techology
IPCC	Intergonmental Panel on Climate Change
UWDS	Uncontrolled Waste Disposal Sites
SUDS	Sustainable Urban Drainage Systems
SLR	Sea Level Rise

13.1 Climate change and infrastructure

Cyprus is an island situated in the north-eastern part of the Mediterranean Sea. Administratively, Cyprus is divided into the following six (6) districts: (a) Nicosia (capital), (b) Limassol, (c) Larnaca, (d) Paphos, (e) Famagusta and (f) Kyrenia (Constantinides, 2002).

The island has a total of 772 km of shoreline, of which: (a) 404 km in the occupied zone; (b)72 km within the British Military Bases; and (c) 296 km under Government control. The critical infrastructure of Cyprus has been developed near the coastal area, except for Nicosia which is located near the center of the island.

According to the Intergonmental Panel on Climate Change (IPCC), the infrastructure is defined as 'the basic equipment, utilities, productive enterprises, installations and services essential for the development, operation and growth of a city or nation'. With respect to the abovementioned definition, in this report when referring to the term infrastructure the following are involved:

- Utility services:
    - Water supply;
    - Energy supply;
    - Wastewater and waste collection, treatment and disposal
- Transport;
- Information and Communications Techology (ICT) infrastructure;
- Industry; and
- Buildings (residential and tourist accommodation units).

The main impacts on the infrastructure sector include: (i) material damages to infrastructure, possibly linked with extreme events and floodings, (ii) disturbances in normal community function such as interruption and obstruction of passenger or freight transport, (iii) human safety.

In Cyprus, it is unclear whether climate change has already affected some of the abovementioned infrustructure (see Section 13.3). However, the main scope of the document was to identify if there are any vulnerable spots regarding infrastructure at present and to examine briefly if there is a potential vulnerability on the sector induced by change in climate factors in the future (see Section 13.4).

Following, in Section 13.2 the baseline situation is discussed. The different types of infrastructure will be presented on the basis discussed above. However, it must be noticed that the presentation was not meant be all-inclusive, but to analyse and give emphasis on the critical infrastructure that is projected to be more sensitive for the case of Cyprus. For example, it was considered by far more important to provide a deeper insight on water infrastructure rather than provide an exhaustive presentation of human settlements.

Finally, it must be noted that 38% of the island territory (including Kyrenia District and the largest part of Famagusta District) is under Turkish occupation. The data presented herein concern the areas under the control of the Government of the Republic of Cyprus.

13.2 Baseline situation

13.2.1 Power plants and electricity network

In Cyprus, the power production is characterized by the following aspects:

- No hydropower production
- No nuclear power production
- Thermal power plants
- Renewable power plants (photovoltaic systems, wind farms and bio-power plants)

To this end the main energy infrastructure comprises (a) thermal power plants producing electricity and (b) electrical lines for the transmission and distribution of electricity. A small fraction of electricity is produced by renewable energy.

Cyprus is an isolated island in terms electrical supply as there exists no interconnection with other countries. As a result, the total amount of electrical energy is produced by oil fired power stations (with a small contribution of renewable energy production). The oil is imported as there are no indigenous energy resources. Cyprus is obliged to keep oil strategic stocks for 90 days consumption. According to the Cyprus Organisation for Storage and Management of Oil Stocks[65] (COSMOS), oil stocks are kept both inside and outside the territory of Cyprus (Greece and Netherlands). An energy center at Larnaca is used for oil storage purposes. It is expected that this center will be soon relocated to the area of Vassilikos.

13.2.1.1 Thermal power plants

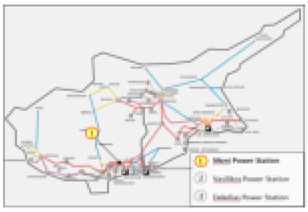
Three main power stations provide the electrical requirements of the island, namely:

- Moni power station;
- Vasilikos power station; and
- Dekelias power station.

Following, these power stations are presented.

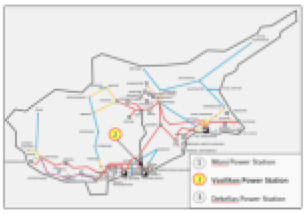
[65] This organization was founded in 2003, for the purpose of maintaining minimum stocks of crude oil and/or petroleum products.

13.2.1.1.1 Moni Power Station



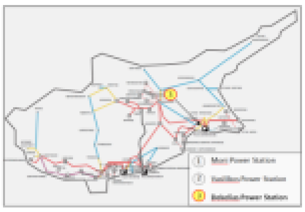
- **Location**: Southern coast of Cyprus (low-land area)
- **Total installed capacity**: 330 MW
  - 6x30 MW, steam turbine units burning heavy fuel oil. The last unit was commissioned in 1976, while the first two in 1966
  - 4x37.5 MW, oil fired gas turbines. The first two gas turbines were commissioned in 1992, while the other two in 1995
- **Thermal coefficient of efficiency**: (a) 25.04%, for the steam turbines and (b) 23.42%, for the gas turbines
- During 2010, Moni Power Station covered 4,98% (259 247 MWh) of the total electrical energy requirements

13.2.1.1.2 Vasilikos Power Station



- **Location**: Southern coast of Cyprus (low-land area)
- **Total installed capacity**: 648 MW
  - 3x130 MW, steam turbine units burning heavy fuel oil
  - 1x220 MW, Combined-Cycle Gas Turbines (CCGT)
  - 1x38 MW, diesel oil-fired gas turbine. This unit was commissioned in 1999 and mainly is used for start-up (black start unit)
- **Thermal coefficient of efficiency**: (a) 38.46%, for the steam turbines and (b) 22.73%, for the gas turbines, (c) 47.95% for the CCGT plant
- During 2010, Vasilikos power station covered 60.77% (3,162,958 MWh) of the total electrical energy requirements

13.2.1.1.3 Dekelias Power Station



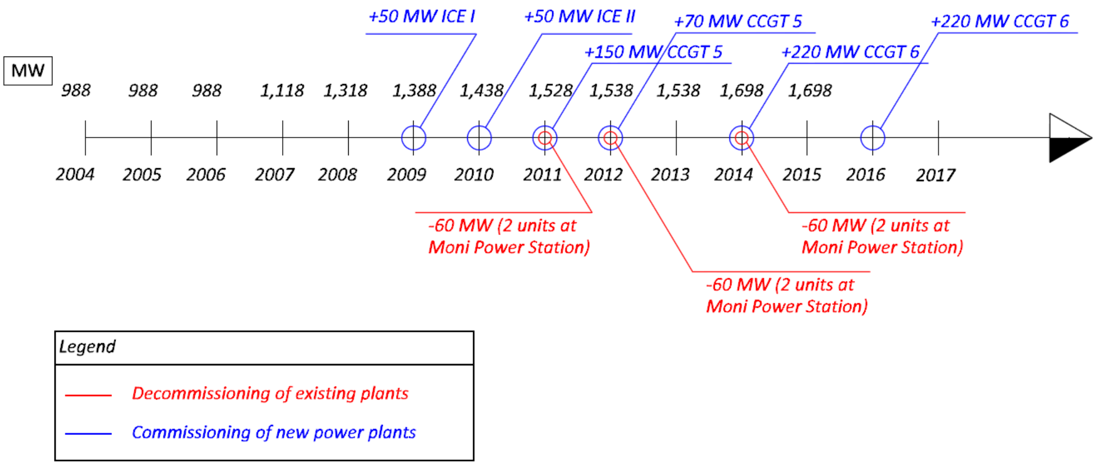
- **Location**: South east coast of Cyprus (low-land area)
- **Total installed capacity**: 460 MW
  - 6x60 MW, steam turbine units burning heavy fuel oil. The last unit was commissioned in 1993, while the first one in 1982
  - 2x50 MW, internal combustion units. The last unit was

commissioned on the 1st of June, 2010.

- **Thermal coefficient of efficiency**: (a) 30.27%, for steam turbines and (b) 41.75%, for internal combustion engines
- During 2010, Dekelias Power Station covered 34.25% (1,782,692 MWh) of the total electrical energy requirements

13.2.1.2 Decomissioning of existing power units/ commissioning of new gas-fired plants

In Figure 11-34 the upcoming changes in the energy infrastructure are described. In specific, the decommissioning of existing power plants is marked with red, while the commissioning of new (notably gas-fired) plants is marked with blue.



Source: Own production (NTUA working team)

Figure 13-1: Installation of new power plants and decommissioning of existing units until 2017.

13.2.1.3 Electrical grid

The existing electricity transmission and distribution network is presented in Figure 13-2. As it can be seen from the figure, the network connects the power stations of the main producer of the island (Electricity Authority of Cyprus) with the load centers and finally to the end-consumers.

The electrical grid consists of:

- the transmission (high and medium voltage) network; and
- the distribution (low voltage) network.

Both of the networks consist of overhead and underground electrical lines as depicted in Figure 13-2.

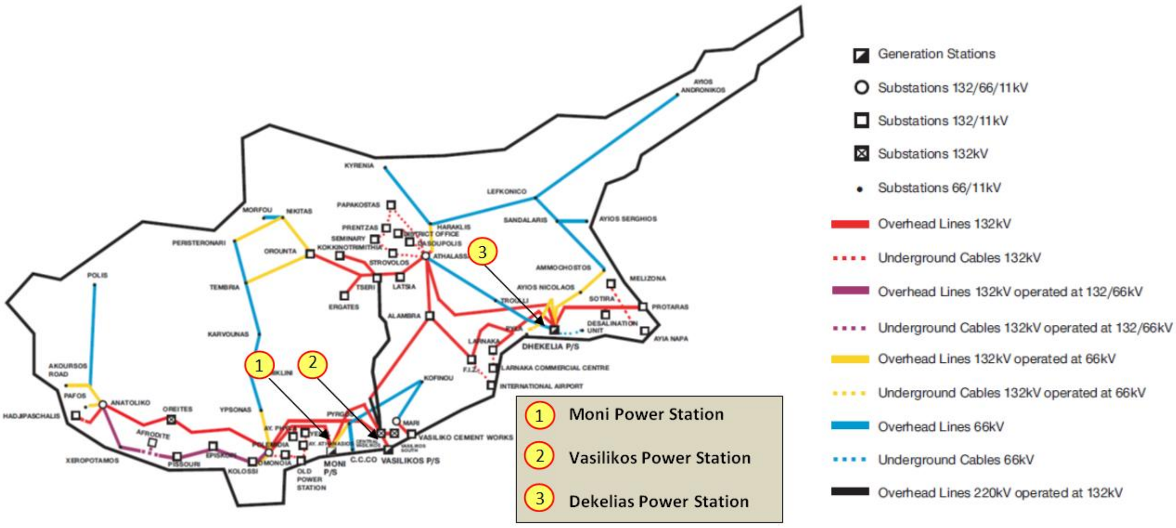


Figure 13-2: Power stations and electrical grid in Cyprus

Source: EAC, 2010

13.2.1.4 Oil stocks storage facilities

Cyprus will meet its obligation towards the European Union to maintain petroleum strategic stocks for 90 days average consumption for the year 2012 as follows (COSMOS):

- Own stocks in Cyprus: 90,600MT
- Own stocks in Greece: 117,700MT
- Tickets in the Netherlands: 210,000MT
- Delegated stocks to EAC: 85,000MT
- Oil Companies Stocks: 74,500MT

The oil companies stocks are located near the coast in Larnaca. The Government of Cyprus has decided due to environmental reasons to decommission these facilities and develop an oil import and storage terminal at Vasilikos. A LNG Terminal was also decided to be developed by EAC at the same place, while after the evaluation of the survey conducted by Noble Energy International Ltd in block 12, the import through pipelines of natural gas is being investigated instead.

13.2.2 Water supply

In Cyprus, the water demand is balanced by the following water sources:

- Water reservoirs (dams): more of 100 dams have been constructed until now with a total capacity of 327.5 million cubic meters (WDD, 2009). The surface water coming from the dams undergoes treatment in water treatment plants before consumption from the end-users;
- Drilling of boreholes;
- Desalination plants: with a total capacity of 180,000m^3/day at the end of 2010, when the desalination plant at Pafos was put into operation;
- Recycled water, which originates from the treatment of waste-water of sewage system

The water supply system also includes the water conveyance infrastructure which is consisted of the following underground pipe network (WDD, 2011b):

- Southern conveyor project (161 km[66]);
- Paphos conveyor project. The amounts of water supply originate from three (3) dams of total water capacity 72.6 million m^3;
- Chrisohous conveyor project. The amounts of water supply originate from four (4) dams of total water capacity 27.2 million m^3 and are used for irrigation purposes;
- North conveyor project. The amounts of water supply originate from four (4) rivers with a total water capacity of 8.5 million m^3;
- Pitsilias conveyor project.;

Two different routes are followed for the delivery of fresh/drinking water to end consumers (see also Figure 13-3):

1. Dams → water treatment plants → water conveyor system → consumption;
2. Desalination plants → water conveyor system → consumption

[66] Total length of southern conveyance system: 161 km (Dhiarizos diversion tunnel: 14.5km, Southern conveyor: 110 km and Tersephanou-Nicosia conveyor: 36.5km). This part of conveyance infrastructure is known as “the southern conveyor project” and it involves water supply both for irrigation and drinking water distribution purposes.

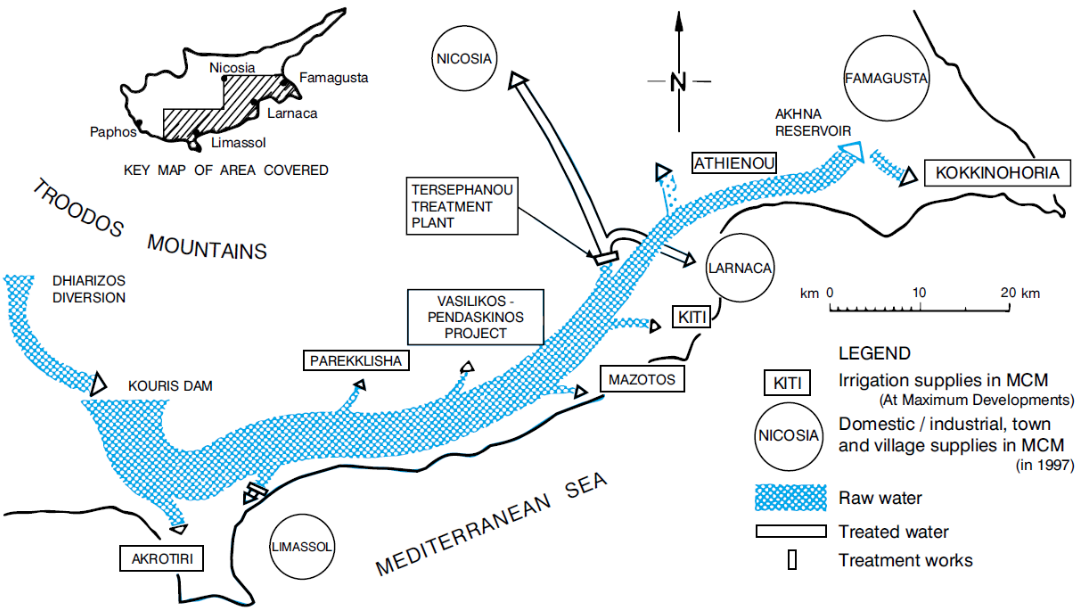


Figure 13-3: Schematic representation of water distribution in the southern part of Cyprus

Excluding the southern conveyance network, it must be noticed that no information, regarding the total pipeline length, has been published from the competent authorities (Water Development Department of Republic of Cyprus). However, it is estimated that till the end of 2012, the WDD will have built a pipe network GIS system mapping a large part of the network (~80-90%)[67]. The same applies for the case of wastewater collection network.

The water supply facilities are summarized below:

Water desalination plants (WDD, 2011c)**:**

Nowadays, Cyprus has two permanent operational desalination plants: the Dhekelia's Desalination Plant with a capacity of 60,000m^3/day and the Larnaca's Desalination with a capacity of 62.000m^3/day serving the needs of Larnaca, Nicosia and Famagusta provinces. There are also two mobile units: the Mobile Unit of Moni with a capacity of 20,000 m^3/day and the Mobile Unit of Paphos with a capacity of 30,000 m^3/day serving the needs of Lemesos and Paphos provinces respectively. Furthermore for Lemesos province's needs, it is operated the Mobile Processing Unit of water from aquifer of Garyllis River with a capacity of 10,000 m^3/day (WDD, 2011c). In the near future, the Government plans the construction of 3 additional permanent desalination plants at Episkopi (Lemesos), Paphos and Vasiliko with capacities of 40,000 m^3/day, 40,000 m^3/day and 50,000 m^3/day respectively (see following Table).

[67] This information has been obtained through communications with the Water Development Department. Contact person: Helena Phinikaridou, e-mail: hphinikaridou@wdd.moa.gov.cy

Table 13-1: Desalination plants of Cyprus and theirs production capacity (WDD, 2011c)

Location	2011	Goal until early 2012
	m^3/day	m^3/day
Larnaca	62,000	62,000
Dhekelia	60,000	60,000
Episkopi	0	40,000
Paphos	30,000 (portable)	40,000
Vasiliko	0	50,000
Moni – movable	20,000	0
Garilli well	10,000	-
TOTAL	**182,000**	**252,000**

It must be noticed that most of the desalination plants are located in low-land, coastal areas (see also Figure 13-6).

Water reservoirs:

In Cyprus, there exist:

- 56 large dams; and
- 51 small dams.

Most of dams in Cyprus are of the earth-fill type, mainly attributed to the nature of the topography and geology of the region where the dam is situated. Economic reasons have also played an important role for selecting this type of dams in Cyprus (WDD, 2009).

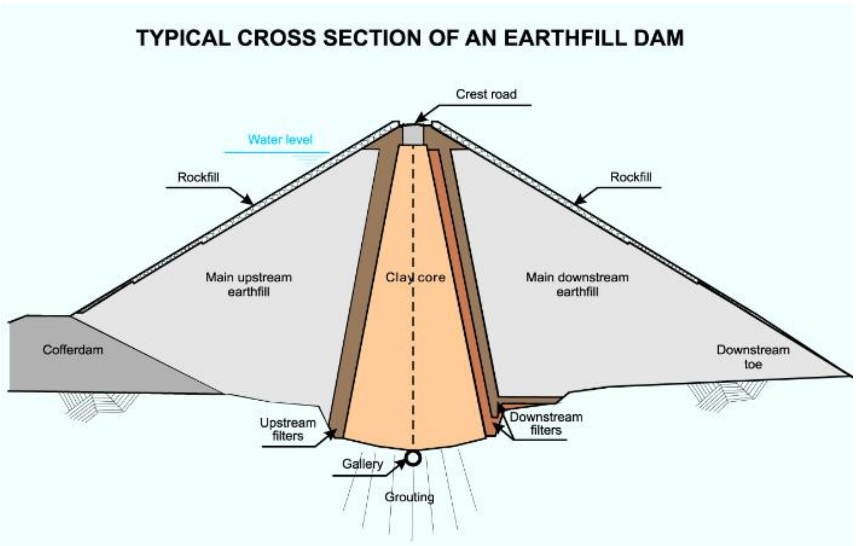


Figure 13-4: Typical cross section of a clay core earth-fill dam.

Source: WDD, 2009

The location of each dam can be seen in Figure 13-5, whereas the reader can find an extensive list with supplementary information (such as catchment area[68] of each dam) in *WDD, 2009*.

Figure 13-5: Dams of Cyprus

Source: WDD, 2009

The surface water from the dams is treated for drinking purposes in the following water treatment plants (data obtained by WDD):

- Pafos;
- Chirokoitia;
- Limassol;
- Tersephanou; and
- Kornos.

It must be noticed that none of the dams consist hydropower dams and are used explicitly for water supply purposes.

[68] The catchment area of a reservoir is that portion of the country naturally draining into it. In the table of the relevant reference (WDD, 2009) it is referred to as 'water-shed' and is expressed in km^2.

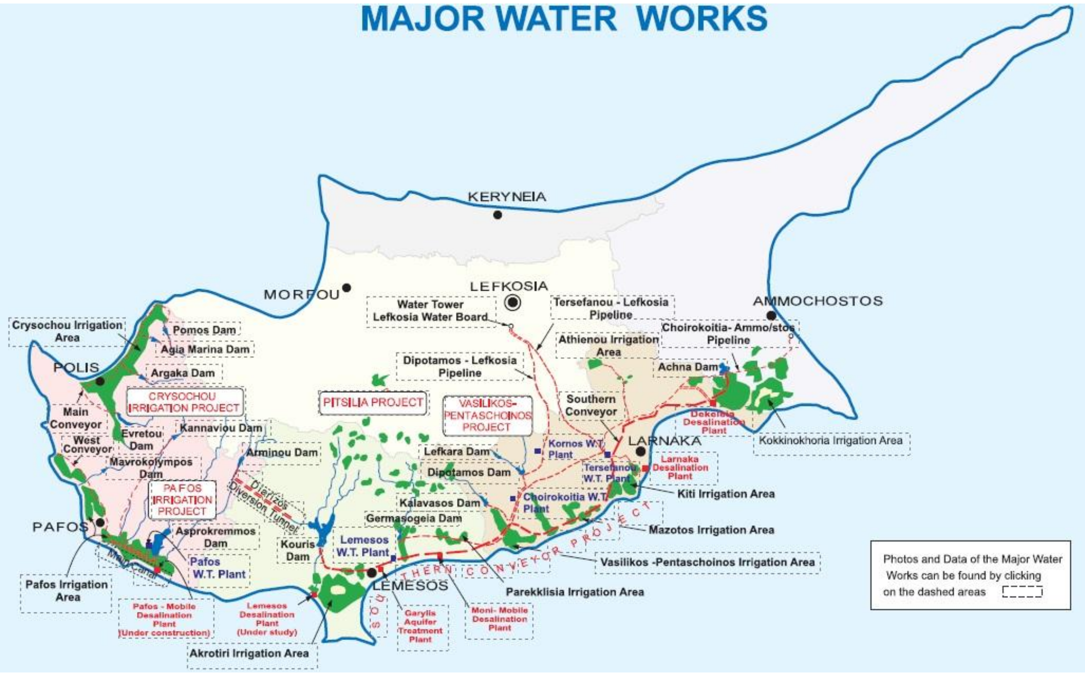


Figure 13-6: Major Water works plants in Cyprus

Source: WDD

As depicted in the above Figure, the major water plants are located within less than a kilometer from the shoreline, something that poses concern regarding the potential rising of sea level, as discussed in Section 13.4.1.

Finally, water supply for irrigation purposes, comes from dams, boreholes and wastewater treatment plants.

Wastewater treatment plants: at present, there exist seven (7) plants in urban areas and seven (6) plants in rural areas and in specific (see also Figure 13-7) (MANRE, 2010b):

Urban areas (MANRE, 2010b):

- Limassol (40,000 m^3/day);
- Anthoupolis (13,000 m^3/day);
- Vathia Gonia (22,000 m^3/day);
- Larnaca (8,500 m^3/day);
- Paphos (8,000 m^3/day);
- Paralimni - Agia Napa (8,000 m^3/day); and
- Vathia Gonia (2,100 m^3/day);

Four out of the seven aforementioned plants are located in or near coastal areas (Limassol, Paphos, Larnaca and Paralimni – Agia Napa plants). However, it must be noted that the plant of Agia Napa is located in higher elevation than Limassol, Paphos and Larnaca plants, which are located in low land areas.

Rural areas (all located at inland of Cyprus) (MANRE, 2010b):

- Dhali (500m^3/day);
- Kyperounta (300m^3/day);
- Pelendri (300m^3/day);
- Lythrodontas (300m^3/day)
- Agros (250m^3/day);
- Platres (200m^3/day);

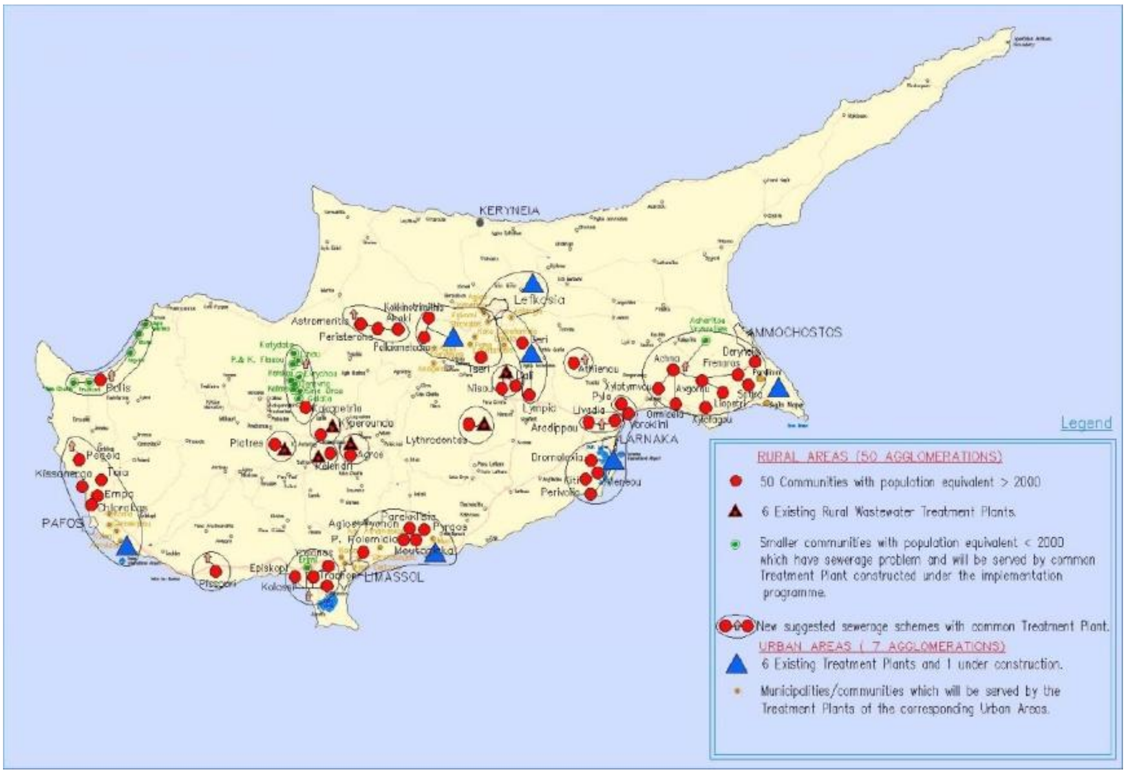


Figure 13-7: Urban wastewater treatment plants in Cyprus

Source: MANRE, 2010b

13.2.3 Solid waste management

In Cyprus, waste management schemes involve:

(a) Waste collection. Municipal Solid Waste (MSW) generated by the cypriot communities, is collected on a regular basis (2 to 3 times a week) (Republic of Cyprus, 2004);

(b) Waste management. Different practices are used currently in Cyprus such as (Republic of Cyprus, 2004):
    - Mechanical treatment, mainly applicable to MSW (Lymbia plant);
    - Biological treatment, mainly used for industrial waste (sludge from wastewater treatment); and
    - Thermal treatment, mainly used for dangerous-hazardous waste (e.g used oils, slaughterhouse waste etc.)

(c) Waste disposal.

It must be noticed that it is outside the scope of this document to record waste management facilities, since landfill sites are the only type of waste sites affected by climate change induced impacts (see Section 13.3.5). In this regard, only landfill sites shall be examined.

At present, two landfills are used in Cyprus (MANRE, 2011):

- Pafos landfill; and
- Koshi landfill (serving the needs of Larnaca and Ammochostos Districts).

It is expected that, by 2014 two landfills shall be put into operation which are now in the design phase (Nicosia and Limassol landfills) (MANRE, 2011).

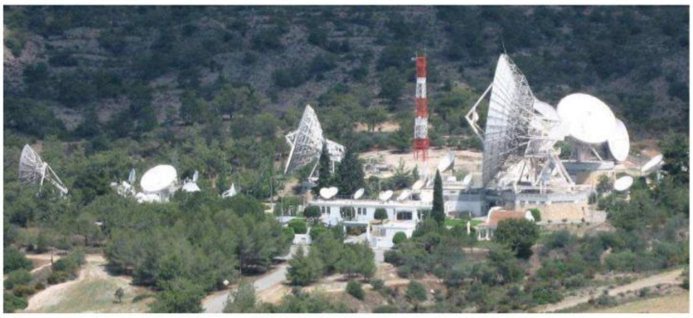
In addition, it must be mentioned that there are approximately 117 Uncontrolled Waste Disposal Sites (*UWDS*) in Cyprus. There is an ongoing plan for the safe decommissioning and restoration to the original state of the sites. It is expected that this plan shall have been completed by 2013 (MANRE, 2010).

13.2.4 Information and Communications Technology (*ICT*)

The communications of Cyprus can be divided into the following two (2) categories:

- Internal communication: this is achieved with the use of an overhead cable network and by means of frequency network; and
- Trans-national communication: this is achieved with the use of two critical infrastructure and in specific (a) the fibre optic cables network, which is submerged into the sea, interconnecting Cyprus with diverse international nodes (Italy, Lebanon, Syria, Israel, Greece)[69] (b) the satellite "Makarios" which is located near Larnaka District (see following figures).

[69] http://www.cytaglobal.com/cytaglobal/userfiles/IRIS2.pdf



Makarios teleport site

National transmission network with international connection

13.2.5 Transport

The transport infrastructure can be divided into three (3) categories:

- Roads;
- Seaports; and
- Airports.

Airports:

- International airports
  - Larnaca
  - Paphos
- Military airports
  - RAF Akrotiri
  - Kingsfield Air Base

Sea ports:

- Limassol port: largest port of Cyprus;
- Larnaca port.

Both ports serve the seaborne cargo and passenger traffic of the island.

Marinas:

- Limassol (under construction);
- Larnaca (under study, tendering stage);
- Aghia Napa (under study, tendering stage).

Fishing shelters:

Fishing shelters are constructed for the protection of small fishing boats against extreme events such as storms and large waves. Currently, there are eleven fishing shelters in operation:

- Ayia Triada;
- Paralimni;
- Ayia Napa;
- Potamos Liopetriou;
- Xylophagou;
- Ormidhia;
- Larnaca;
- Agios Georgios Pegeias;
- Pomos; and
- Pyrgos.

The construction works for the new fishing shelter at Zygi started in December 2007 and were completed in 2011. The fishing shelter will have the capacity of 220 vessels, and will also assist in the socioeconomic development of the area.

Fishing vessels are also harboured at Latsi and in the ports of Paphos, Limassol and Larnaca (Department of Fisheries and Marine Research).

Fishing Shelter of Paralimni

Fishing Shelter of Paralimni

Fishing Shelter of Potamos Liopetriou

Road network:

The main means of transport in Cyprus is the car. It is reported that, the per 1,000 people car ownership rate in Cyprus is the highest in the world (742 cars/1,000 people), shedding light on the high energy use of the transportation sector which accounted for 55.1% of the final energy consumption in 2009. Besides car transportation, the share of public transport is estimated at 3%, followed by bicycle use (less than 2%). Moreover, it must be noticed that there is no railway transportation in Cyprus, pointing out that motorways substitute the only significant infrastructure of the island (excluding seaports and airports) (MANRE, 2011).

The total length of motorways in 2009 totaled 257 km (Eurostat). Finally, it must be noticed that in Cyprus there are a number of small bridges in the road network.

Figure 13-8: Road map of Cyprus

Source: MCW, 2006

13.2.6 Other infrastructure

Under the other infrastructure category the following are included:

- Industry;
- Hotels; and
- Buildings.

13.2.6.1 Industry

The main industrial activity in Cyprus comprises the following sectors[70] (MLSI, 2011):

- Cement production (2 installations);
- Ceramics production (8 installations);
- Lime production (1 small-scale production plant);
- Foundries (1 installation);

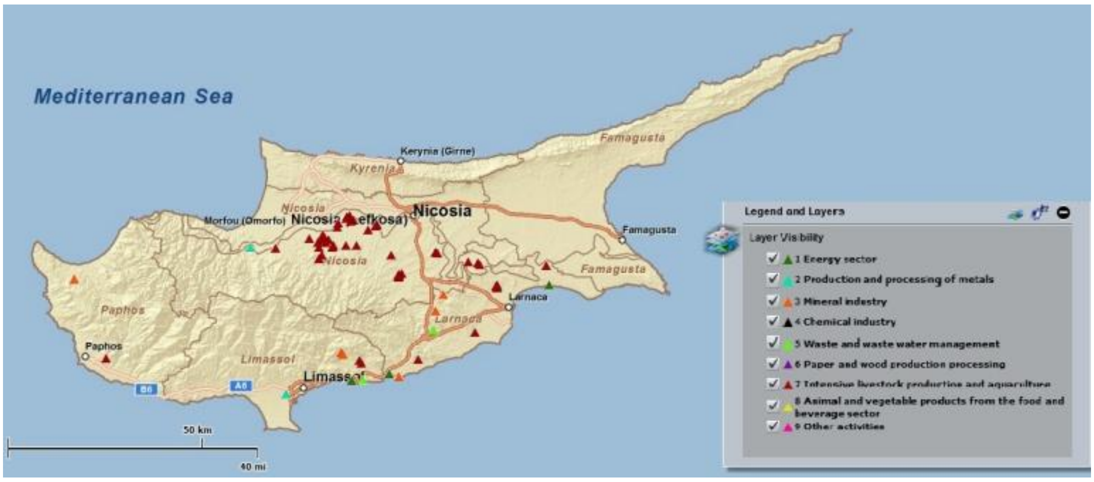


Figure 13-9: Industry facilities by sector in Cyprus

Source: http://prtr.ec.europa.eu/IndustialActivity.aspx

13.2.6.2 Hotels

More than 800 tourist accommodations are in operation today (CARBONTOUR, 2010). As it can be seen by the following figure, these accommodation units have been developed near the urban centers of Cyprus the vast majority of which are located near the coast line of the island, which corresponds to a 95% share of the total tourist accommodation units of Cyprus (the rest are located in Nicosia and the mountain resorts) (Constantinides, 2002).

[70] The following installations were in operation and terminated as follows: (a) one petroleum refinery (terminated in March 2004), (b) 2 foundries (2005)

Figure 13-10: Hotels in Cyprus

Source: googlemaps

13.2.6.3 Buildings

The total building stock of Cyprus amounts approximately to 242,000 houses. It has been estimated that single house has the highest share (44%), followed by apartments (21%), duplex houses (17%) and other type of buildings[71](Panayiotou, 2010).

Spatial development in Cyprus is characterized by rapid population growth in the suburbs of the urban centers (sub-urbanisation). According to the Statistical Service of the Republic of Cyprus (Statistical Service, 2009), the urban areas[72] by district are the following:

- **Nicosia**: Municipal boundaries of Lefkosia Town, Strovolos, Aglantzia, Agios Dometios, Egkomi, Kato and Pano Lakatameia, Latsia and Geri.
- **Famagusta** Does not include any urban areas
- **Larnaca**: Municipal boundaries of Larnaca Town, Aradippou and Livadia, Dromolaxia, Meneou, Oroklini and Pyla coastal Zone;
- **Lemesos**: Municipal boundaries of Lemesos Town, Agios Athanasios, Mesa Geitonia, Kato Polemidia and Germasogeia, Amathounta, Pano Polemidia, Ypsonas.
- **Pafos**: Municipal boundaries of Pafos and Geroskipou, Chlorakas, Lempa, Empa, Tremithousa, Mesogi, Mesa Chlorio, Anavargos, Konia, Agia Marinouda, Koloni, Acheleia, Tala, Kissonerga, Coral Bay.

[71] The survey concerned a sample of 500 houses

[72] The urban area is determined by the municipal boundaries of the main towns and adjacent suburbs, all other areas are classified as rural.

As obvious, the urban centers of Cyprus (excluding Nicosia) are all situated in or near coastal areas. This indicated the other dominant feature of the spatial development of the island which is coastalization. To this end, the majority of settlements, as well as other critical infrastructure including hospitals and schools, is situated in coastal areas.

Finally, the land use in coastal areas is as follows (Konstantinides, 2003):

- Tourist zones: ~103 km;
- Open areas/protected archaeological zones: ~125 km;
- Agricultural zones: 36 km;
- Residential zones: ~17 km; and
- Industrial zones: ~9 km.

13.3 Impact Assessment

The climatic factors that are likely to induce impact on the infrastructure sector are the extreme events. More importantly, heavy rain and sea level rise comprise the most important climatic factors among extreme events that should be examined for measuring the impact on infrastructure.

Following, the potential climate-induced impacts on the infrastructure sector in general, and for the case of Cyprus in particular are recorded. To this end, the approach of this work is to provide, where possible, quantified results in order to measure to the greatest extent the impact on each infrastructure category.

In the context of the quantitative impact assessment the indicators presented in Table 13-2 have been examined.

Table 13-2: Relationship between observed climate changes and impacts on the infrastructure sector

Climate factor	Impacts on infrastructure		Selected Indicators
	Type of Infrastructure	Impact	
Heavy rain	All types	• Flood • Landslides	• Severity of material damages to infrastructure
	Water infrastructure (wastewater collection and treatment)	• Risk for flooding of Sewerage Treatment Plants • Risk for sewer flooding	
	Transport infrastructure	• Increased demand for car use • Flooding of underground networks • Flood damage • Bridge collapse and associated implications (transport communication, safety risks etc.)	
	Communications	• Reliability of the signal • Disturbances to overhead cable networks	• Disruption frequency • Duration of disruption
Storm surge	All types (located at coast)	• Flood • Periodic flooding of coastal infrastructure	• Percentage of critical infrastructure located in or near coastal areas

Climate factor	Impacts on infrastructure		Selected Indicators
	Type of Infrastructure	Impact	
			• Disruption frequency in daily operations (social activity and trade) • Duration of disruption
Sea Level Rise	All types (located at coast)	• Permanent asset loss at coastal sites •	• Percentage of critical infrastructure located in or near coastal areas
	Transport infrastructure (ports)	• Limited access to ports • Threat to port operation	• Coastal infrastructure asset losses due to Sea Level Rise
High winds	Transport	• Transport disruption (caused by blown down trees etc.) • Impede aircraft operation	• Disruption frequency in daily operations (social activity and trade) • Duration of disruption
Temperature increase	**Transport**	• Deformation of road and airport asphalt surfaces • Passenger discomfort	
	Communications	• Decreased wireless transmission signal	
Extreme events	**All types**	• Risks for human safety	• Number of accidents related to extreme weather events • Population living in disaster prone areas (areas prone to flooding and landslides) • Changes in the proportion of built-over land in disaster prone areas
	Transport infrastructure	• Asset failure due to long, hot, dry periods followed by intense rain causing flash floods. • Stability of foundations of transmission masts and towers, mostly attributable to increased risk of subsidence (more	

Climate factor	Impacts on infrastructure		Selected Indicators
	Type of Infrastructure	Impact	
		susceptible during drier summers and wetter winters) • Damage to underground cables(more susceptible during drier summers and wetter winters)	

The aforementioned impacts induced by climate change are presented in detail next by type of infrastructure.

13.3.1 Water infrastructure

The water infrastructure can be divided into the following two categories:

- Water supply, treatment and storage infrastructure;
- Wastewater collection, treatment and disposal infrastructure.

13.3.1.1 Storage reservoirs, water supply and treatment infrastructure

The climate factors that are likely to affect the water supply system are the following: (a) decreased precipitation; (b) sea-level rise; and (c) heavy rain and extreme events (SEFRA, 2011).

Decreased precipitation
Decreased precipitation is mainly linked with consequent decreased water availability, rather than with vulnerability of water infrastructure (see Section 3 “Water Resources”).

Sea-Level Rise
Sea-level rise, may affect both water availability (as a result of increased salt intrusion into coastal underground systems) and flooding of infrastructure near coastal areas.

Heavy rain and extreme events
The main impacts on the sector are related to extreme events (heavy rain, droughts etc.) which can: (a) reduce the security of water supply, (b) increase infiltration to networks, (c) cause damage to the water supply infrastructure: for instance, dams may collapse due to overflow caused by extreme flows. This was the case in 1985 when the Noppikoski dam in Sweeden collapsed (Sweedish Government, 2007). Fortunately, it did not cause any deaths, but rather same material damages downstream.

What is of particular importance is that the location of dams comprises a key aspect for assessing the risk induced by a possible failure. In other words, the failure of a dam located in a rural area with a limited storage capacity can have little or no effect on those living in the County. On contrary, a large dam situated near an urban center raises by far greater concern over a possible failure.

Box 1: Failure of dams (Antoniou, 2007)

The failures of dams are of particular importance, since the magnitude of the disasters that they can cause is enormous, both in terms of loss of lives and of property damage. This is attributed to the destructive power of the flood wave caused by the sudden collapse of a large dam.

When studying the effects of a dam the following two discrete aspects must be taken into consideration:

- **Risk:** The risk is defined as the probability of a dam to fail. Regardless of how well the dam is constructed and maintained, the risk of failure cannot be reduced to zero. A dam may have little risk of failure but may cause high downstream hazard when the failure occurrs, especially when large numbers of people live in the flood zone of the dam.
- **Hazard:** is defined as the potential effects of a dam failure, including the possible loss of life or damage to property downstream of the dam, caused by overflow of dams or by waters released due to partial or total failure of the dam.

All dams have some risk for failure, no matter how low this is, but the hazard to the public or property must always be taken into consideration

As a result, although the failure of a dam may be a rare phenomenon (low risk), it may induce safety risks (loss of lives and destruction of property) in downstream inhabited areas (downstream hazard).

Situation in Cyprus:

- Number of accidents related to extreme weather events: **No data**
- Severity of material damages: **No data**

Relevant data, linking water infrastructure data with climate change, is still lacking. Following, an indicative list of damages caused to water supply facilities is presented. It must be noticed that these impacts cannot be directly connected with climate change. However, the monitoring of the number of events/disasters over a particular time period (e.g over a year), can provide a basis (indicator), which will allow the climate-induced impacts and the vulnerability of the sector to be measured.

According to the records kept by the Water Development Department (WDD, 2011) since 1859, a number of floods have occurred. The incidents, which are related to water supply infrastructure damage and occurred during the last century, are the following:

- **1918**: The water supply infrastructure at the region Pediaio, Limassol (Arab-Ahmet aqueduct) was damaged;
- **1936**: The water supply infrastructure of Lemesos (Tzitromilin aqueduct) was damaged;

- **1968**: Two water tanks with a total capacity of 40 million gallons were destroyed, causing damages to agricultural crops situated nearby;
- **1979**: one dam (water retaining facility) collapsed due to extreme flow[73], resulting to serious damages in households and road infrastructure;

The collapse of the dam in 4/10/1979 in Makedonitisa, which is situated in the area of Egkomi (district of Nicosia) comprises an isolated incident and its impact was overstressed by the local media. The dam is in fact a small retaining facility. The impact of the failure of the water retaining facility was characterized as minor.

However, in Cyprus many dams are situated near urban centers. In order for the impact of a possible failure to be measured, it is essential to examine also the type of the dams as well as its main source of failure mechanisms.

As mentioned in Section 13.2.2, most of these dams are of the earth-fill type. A study on the causes of 220 earth-fill dam failures[74] conducted by Middlebrooks (Antoniou, 2007) during the period 1850 to 1950, presents the factors which account for the failures in such dams (see Table 13-3).

Table 13-3: Causes of Earth Dam Failures 1850-1950

Cause	Source Mechanism	% of Total
Overtopping	Flood	30%
Piping/Internal erosion of embankment or foundation	Seepage, piping and internal erosion	25%
Conduit Leakage		13%
Damage/ Failure of upstream membrane/ slope paving		5%
Embankment instability-Slides	Varies	15%
Miscellaneous	Varies	12%

Source: Antoniou, 2007

According to Antoniou and with regard to earth-fill dams (Antoniou, 2007), it was recorded that some 50% of failures occur during the first five years after the construction of the dams and 19% during their first loading (see following table). In Cyprus, most of these dams are relatively new and consequently they cannot be categorized as vulnerable infrastructure.

[73] The extreme flow was caused by heavy rain which lasted around 3 ½ hours (13^{30} – 17^{00}pm). Even if

[74] The failures of the dams can be categorized according to the level of the stored water into the following categories: (a) 'sunny day' failure (stored water < capacity of dam), and (b) overflow failure (water level ~ maximum) (Antoniou, 2007).

Table 13-4: Dam Failures – Age of Dam at time of failure

Number of years after completion	Cause of Failure				Total
	Overtopping	Conduit Leakage	Seepage	Slides	
0 – 1	9	23	16	29	19%
1 – 5	17	50	34	24	31%
5 – 10	9	9	13	12	11%
10 – 20	30	9	13	12	16%
20 – 50	32	9	24	23	22%
50 - 100	3	0	0	0	1%

Source: Antoniou, 2007

Sudden, heavy rain has been monitored since 1930 by the Meteorological Service of Cyprus (see Figure 13-11). The analysis of the data has shown a rising trend between 1930 and 2007, which there is evidence that is related with climate change. An increase, both in terms of frequency and magnitude, in flood events has also been observed (see Figure 13-12).

No impact assessment study has been elaborated regarding the dams and their sensitivity to climate change. Thus, relative research is recommended for assessing the risk of a possible dam failure and the hazard that can be caused to downstream areas.

However, for the purpose of comparison with the impacts induced on the other sectors and only, it is suggested that:

- the impact on water supply sector can be characterized rather insignificant

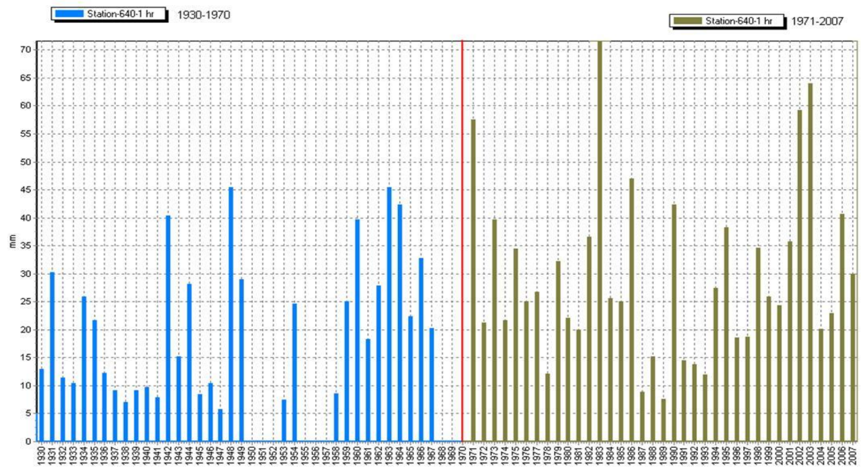


Figure 13-11: Highest amounts of rainfall in 1 hour, in Cyprus

Source: Pashiardis, 2011

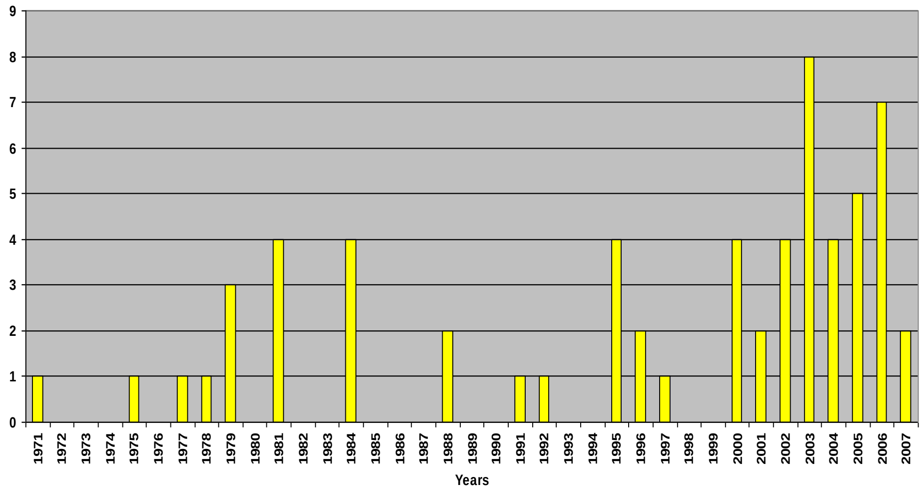


Figure 13-12: Number of flooding events per year

Source: Pashiardis, 2011

13.3.1.2 Wastewater collection, treatment and disposal infrastructure

The impacts associated with climate change on the wastewater infrastructure are summarized in Table 13-5.

Table 13-5: Impacts associated with climate change on wastewater infrastructure

Climate factor	Impacts on wastewater infrastructure
Extreme events	
Heavy rain	Risk for sewer flooding
	Risk for water pollution and public health in case wastewater reaches an underground water reservoir which is used for water supply of the community.
	Risk for flooding of Sewerage Treatment Plants

Situation in Cyprus

In Cyprus, there are seven (7) urban agglomerations and fifty (50) rural agglomerations. Administratively, the latter agglomerations are under the responsibility of Water Development Department (WDD), while the former under the responsibility of six (6) pubic authorities (urban sewerage boards), namely:

- Sewerage board of Nicosia (SBN); 1300km wastewater collection piping length[75]
- Sewerage board of Limassol-Amathus (SBLA); its infrastructure involves 350km[76] wastewater collection piping length;
- Larnaca Sewerage and Drainage board (LSDB): its infrastructure involves 100km of sanitary sewers, 17 sanitary pumping stations and the sewage treatment plant, which is situated south of the Larnaca International Airport.
- Sewerage Board of Polis Chrysochous (SBPCh):
- Sewerage Board of Paphos (SPA): its infrastructure involves 175km of sanitary sewers
- Sewerage Board of Paralimni – Agia Napa (SBPNA): its infrastructure involves 110km of sanitary sewers

The total length of collection network (including the piping length that is planned to be added to the existing network) amounts to 4,313 km, with urban agglomerations having a share of 64.2% (2,770km). WDD expects to have built a pipe network GIS system, mapping therefore a large part of the network (~80-90%) till the end of 2012.

Regarding the sewerage system of Cyprus, it must be said that there have been recorded flooding events, which are mostly attributed to mixing of the sanitary sewerage and drainage streams into a common stream ending to the sewerage system. These events have been followed in certain cases by tragic events, as occurred in 20/11/1996, when a guardsman fell into the sewer system and found tragic death in Limassol.

[75] This information is unpublished and was provided through contacts with SBN. Contact person: Panayiota Hatzioanna, e-mail: k.panayiota@sbn.org.cy

[76] This information is unpublished and was provided through contacts with SBLA. Contact person: Mihalis Vrionides, e-mail: vrionides@sbla.com.cy

13.3.2 Transport

The transport sector can be divided into the following categories, as discussed in Section 13.2.5:

- Road transport;
- Rail transport;
- Sea-ports, marinas, fishing shelters and
- Airports.

The main impacts on the transport sector are presented in Table 13-6 (DfT, 2010).

Table 13-6: Climate factors and associated impacts on the transport infrastructure sector

Climate factor	Impacts on transport infrastructure
Increase in temperature	Deformation of road and airport asphalt surfaces
	Passenger discomfort
Extreme events	
Heavy rain	Flood damage
	Increased demand for car use
	Flooding of underground networks
	Bridge collapse and associated implications (transport communication, safety risks etc.)
Sea Level Rise (SLR)	Permanent asset loss at coastal sites
	Periodic flooding of coastal infrastructure
	Limited access to ports
	Threat to port operation
High winds	Transport disruption (caused by blown down trees etc.)
	Impede aircraft operation
Combined extreme events (drought & flash floods)	Asset failure due to long, hot, dry periods followed by intense rain causing flash floods.

Situation in Cyprus

- **Road transport**

According to the records kept by the Water Development Department (WDD, 2011) since 1859, a number of floods have occurred with multiple implications in road infrastructure, such as:

- Transport disruption and road damage: 1918 (11/12/1918 and 21/12/1918), 1936, 1984 (04/11/1984), 2005 (31/05 – 01/06/2005), 2010 (18/01/2010) etc.
- Collapse of bridges:

  - **February 1901**: Three bridges collapsed in the region between Nicosia and Idaliou;
  - **August 1906**: The bridge of Plakos river collapsed;
  - **11 December 1918**: Serious damages in roads and bridges in the whole area of Cyprus;
  - **11 December 1918:** A number of small bridges collapsed (approximately 20), as also the largest part of Strovolos bridge.
  - **1936**: The bridges of South Amiantos, Pera Pedios and Limnati collapsed, while the bridge near Skouriotissa area was seriously damaged;
  - **24 October 1967**: The bridge in the road Avlonas-Filia collapsed;
  - **25 December 1968**: The bridge Ha-river collapsed. Two taxi-cars fell into the river posing the passengers (5) in high risk; and
  - **12 February 2003**: One bridge collapsed in the area of Dali.

Moreover, as presented in Table 13-6, urban floods (mainly caused by failure of the drainage system) are likely to lead to flooding of underground networks. However, there is no underground transportation (metro) in Cyprus. Consequently, no such impact applies for the case of Cyprus at present.

- **Rail transport**

Severe damages have been recorded in rail transport as in 1906 (12/08/1906), 1918 (21/12/1918), 1921 (08/06/1921) etc. However, rail transport operated from October 1905 to December 1951 and has never been used ever since.

- **Ports**

No significant impacts have been recorded.

- **Marinas**

No significant impacts have been recorded.

- **Fishing shelters**

Minor impacts have been recorded due to surge waves.

- **Airports**

- In Larnaca on the 19th of December, 2002 the corridor of the International Airport was flooded, hindering the landing of two civil aircrafts.

13.3.3 Energy infrastructure

The impacts on the energy infrastructure can be grouped into the following categories:

- Power generation;
- Electricity transmission and distribution;
- Fuel processing and storage.

13.3.3.1 Power generation infrastructure

The main concerns regarding power generation infrastructure lie in fossil-fuel and nuclear power plants. Whereas, fossil-fuel powered plants relate exclusively with implications for infrastructure damage and disruption in electrification, nuclear power plants pose also safety risks.

It is worth noticing that climate change is likely to affect power generation. More particularly, reduced power generation in response to increasing temperature levels is expected due to reducing thermal coefficient of efficiency of power plants. The reader can find more information in Section 0 (energy sector), where the impacts on the energy sector are presented in detail.

Situation in Cyprus

There are no nuclear power plants in Cyprus.

A major damage has been observed in the power generation infrastructure of Cyprus. In particular, Vasilikos Power Station suffered severe damages in 11/07/2011. However, this infrastructure damage is attributed to an explosion of a military base nearby (Mari Naval Military Base), and cannot therefore be related to climate change.

Finally, as it is shown in Figure 13-2, all power stations of the energy infrastructure of Cyprus are situated in coastal areas.

13.3.3.2 Electricity transmission and distribution

The impacts on electricity transmission and distribution involve: (a) the reliability of the system and (b) reduced electricity capacity.

Should extreme climate phenomena happen such as flooding, heat waves and droughts, the infrastructure must be able to withstand the changes and guarantee that the electrification shall not be put at risk. Another potential source of disruption of overhead cables used for electrification (and also for communication purposes), is storm winds through falling trees.

Moreover, when referring to reduced electricity capacity, it must be stressed that according to thermodynamics, there is a small increase in line resistance with increasing mean temperatures (Santos et al., 2002).

Situation in Cyprus

In Cyprus, a minor part of transmission cables (~9%[77]) and a more significant part [~37.6% for medium voltage (MV) equipment and 32.5% for low voltage (LV) equipment[78]] of distribution equipment [22,427.64km which corresponds to 95.7% of the route length of electricity (transmission and distribution) equipment], has been installed underground.

Moreover, according to WDD (WDD, 2011) the electrification has been disrupted due to heavy rain as it occurred in 21/11/1994, when several villages experienced electricity cut and in 10/10/1996 when the electrical infrastructure (distribution equipment such as electric cables and pylons) were seriously damaged.

Finally, the electrical losses of the electrical energy system of Cyprus accounted approximately for 2.8% (145,718 MWh). Even though no impact has been observed until now associated with climate change, it must be noticed that there exist studies (Saarelainen, 2009) showing that this figure is expected to increase in the coming years, requiring possible redesigning of the cables.

Until now, it can be said that a limited body of knowledge is available for this impact in Cyprus. As presented in Section 13.2.1.3, the most significant part of distribution equipment is installed near coastal areas, where the majority of Cyprus urban centers are situated. This fact poses implications for risk of infrastructure damage associated with storm surges or/and sea-level rise.

To this end, given that power plants and significant part of the electricity transmission equipment are situated near the coastline of the island, the rise of sea level must be well studied and understood, in order to avoid flooding risk of future power plants and protect existing infrastructure.

13.3.3.3 Fuel processing and storage

The main impact lies in flood risk of fuel processing and storage facilities.

[77] Total route length of transmission equipment: 997.76 km (906.32 km overhead cables, 91.44km underground cables)

[78] Total route length of distribution equipment: 8787.76 km MV (5,482.38km overhead cables, 3,305.38km underground cables) and 13,639.88 km LV (9,205.98 overhead cables, 4,433.9km underground cables)

Situation in Cyprus

Cyprus has no longer fuel processing industries, while it is obliged to keep oil strategic stocks (see Section 13.2.1.4). The facilities which will be used for the oil stocks are expected to be installed at Vasilikos.

More particularly, the following facilities shall be installed:

- Energy center of Vasilikos: the energy center is expected to accommodate also facilities for natural gas exploitation (liquification plant);
- One terminal installed by a private company (VITOL) which will be built in the industrial zone of Vassilikos, the completion of which is expected in the second half of 2012. The terminal will be consisted of 19 tanks and will supply the domestic market in Cyprus by means of truck access.

It must be noticed that the above mentioned facilities will be situated close to Cyprus shoreline.

13.3.4 Information and Communications Techology (*ICT*) infrastructure

ICT infrastructure can be grouped into the following categories:

- Wireless infrastructure; and
- Copper and fibre optic cables.

Following, the climate factors that are likely to have an impact on water infrastructure are presented (SEFRA, 2011).

Table 13-7: Climate factors and associated impacts on wireless and cable network infrastructure

Climate factor/impact	Impacts on wireless I/f	Impacts on cable network I/f
Temperature increase	Decreased wireless transmission signal	-
Extreme events		
Heavy rain	Reliability of the signal	Disturbances to overhead cable networks
Sea Level Rise (SLR)	Permanent asset loss at coastal sites	
Drier summers and wetter winters	Stability of foundations of transmission masts and towers, mostly attributable to increased risk of subsidence	Damage to underground cables

Situation in Cyprus

In Cyprus, heavy rain has caused disturbances in the telecommunication sector in the past. Indicatively, according to WDD (WDD, 2011) in 04/11/1984 in the area of Strovolos the communication network suffered significant damages (the underground cable network was flooded in three different places), resulting to disruption of the network functionality.

No significant impacts have been observed in Cyprus.

13.3.5 Waste management

Waste management is one of the main municipal utility services and therefore it is essential to be carefully addressed.

The main impacts associated with waste management involve the risk for transport of wastes and storage of waste materials in landfills. When referring to risk related with landfill storage, the main implication lies in the potential waste leachate in case surface floodwater reaches the landfill site (Saarelainen, 2006).

In Cyprus, no such impacts have been observed.

13.3.6 Buildings

Even if the industry sector and hotels have been separately presented in Section 13.2, they can be all seen under buildings category with regard to the impacts induced by climate change.

The impacts on the buildings sector involve damages in the infrastructure mainly attributable to extreme events such as intense wind, snow and floods. It must be mentioned that flooding of buildings can be caused due to heavy rain as well as due to sea-level rise. Regarding the former, in Cyprus there has been observed a large number of events, the most recent of which are:

- ❖ **27/10/2009**: Thirty houses were flooded in the community of Alambras, causing significant material damages;
- ❖ **11/01/2006**: Different buildings suffered significant damages including enterprises (coffee shops and hotels) and houses (12 houses were flooded). The flooding event occurred in Agia Napa, Paralimni region;
- ❖ **14/05/2001**: Government buildings, houses as well as the General Hospital of Nicosia suffered damages from floodings due to heavy rain, the intensity of which totaled 14.5mm.

13.3.7 Conclusions

As described in the above sections, the sector of infrastructure has been affected mainly by the following two main categories of impacts:

- Material damages; and
- Disruptive operation.

For the case of Cyprus, the above mentioned impacts are related with flooding events induced by heavy rain (flash floods). However, there is no evidence that these events are directly connected with climate change and as a result the impacts due to climate change on the infrastructure sector are limited to **uncertain**. The available data were not conclusive and could not be used as a basis for measuring the impact of climate change on infrastructure. To this end, at most cases no values are attributed to indicators.

It is worth saying, however, that there is an increasing trend in the appearance of flooding events, the intensity of which, both in terms of frequency and severity, is likely to exacerbate due to climate change.

In general, it must be noticed that sensitivity of the sector is increasing in flood and landslide prone areas (MoE, 2011). In this respect, in Section 13.4, a discussion is provided over these concerns for potential future vulnerabilities of the Cypriot infrastructure system.

13.4 Vulnerability assessment

In this section, the vulnerability of the infrastructure sector is assessed in terms of its sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Cyprus. In particular, sensitivity is defined as the degree to which the infrastructure sector is affected by climate changes, exposure is the degree to which the infrastructure sector is exposed to climate changes and its impacts while the adaptive capacity is defined by the ability of the infrastructure sector to adapt to changing environmental conditions which is also enhanced by the measures implemented in Cyprus in order to mitigate the adverse impacts of climate change on the sector.

The indicators used for the assessment of sensitivity, exposure and adaptive capacity of the Cypriot energy sector to climate change impacts are summarized in Table 13-8.

Table 13-8: Indicators used for the vulnerability assessment of climate change impacts on the infrastructure sector of Cyprus

Vulnerability Item	Selected Indicators
Damage of infrastructure from urban floods	
Sensitivity	– Change in frequency, intensity and severity of extreme events – Severity of damages caused to infrastructure
Exposure	– Changes in the proportion of built-over land in disaster prone areas – Changes in land use
Adaptive capacity	– Flood protective measures (drainage works, SUDS etc.)
Damage of infrastructure from sea floods	
Sensitivity	– Change in frequency, intensity and severity of extreme events – Severity of damages caused to infrastructure
Exposure	– Number of critical infrastructure located in or near coastal areas – Changes in the proportion of built-over land in disaster prone areas – Frequency of sea flooding events
Adaptive capacity	– Land lift-up (Autonomous adaptive capacity for SLR) – Flood protective measures (coastal defense works, breakwaters, retaining walls, fishing shelters, etc.)
Damage of infrastructure from landslides	

Vulnerability Item	Selected Indicators
Sensitivity	- Slope stability (geology, soil composition)
Exposure	– Proportion of built-over land in landslide prone areas
Adaptive capacity	- Relocation of settlements - Landslide protection measures (road protections measures for landslides, retention walls etc.)

The relationship between sensitivity, exposure and adaptive capacity is based on the following qualitative equation:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

Sensitivity, exposure and adaptive capacity are evaluated on a 7-degree qualitative scale ranging from “none” to “very high”.

To assess the vulnerability of infrastructure sector, the following impacts were considered:

1. Infrastructure damage due to floods (urban and sea floods); and
2. Infrastructure damage due to landslides.

It must be noted that, there are no sufficient scientific evidence and data to evaluate or correlate all impacts and indicators to climate changes. Consequently, further research is required in order to provide concrete information for a more detailed and descriptive assessment of the vulnerability of the sector. Nevertheless, an attempt was made to provide a preliminary assessment of the vulnerability. In case additional data are provided by the competent authorities of Cyprus, the vulnerability of the sector could be re-assessed.

13.4.1 Damages of infrastructure due to floods

The vulnerability of the Cypriot infrastructure was assessed regarding the following two types of floods:

- Sea floods;
- Urban floods.

13.4.1.1 Assessment of sensitivity and exposure

Sensitivity: Any minor change in the intensity, in frequency or severity of extreme events (storm surges, heavy rain) shall induce serious impacts on infrastructure.

Sea floods
Given that Cyprus is an island characterized by coastal infrastructure development, the main concern relates to flood events due to storm surge or sea-level rise (mainly affects coastal infrastructure). However, no significant flood events have been recorded and thus the sensitivity of the infrastructure due to sea floods was ranked as **limited**.

Urban floods
Urban floods are directly connected with heavy rain. Various flood events have been recorded until now (see Section 13.3). According to the records kept by the Water Development Department (WDD, 2011), between 1859 and 2011, Cyprus has suffered over 200 floods that have caused implications in multiple levels such as damages to road infrastructure, disruption of economic, social and cultural activities and in turn financial losses.

Timing: in the time-scale of climate change projections (50 – 100 years) no significant changes in the occurrence of flood events are expected (WDD, 2011). Information for a more specific prediction is very scarce and uncertain (WDD, 2011d).

In this regard, the sensitivity of infrastructure due to urban floods was ranked as **moderate** to **high**.

Exposure:

Sea floods
However, in order to estimate the exposure to floods from the sea, it is essential to examine which infrastructure is located in or near coastal areas. In Cyprus this infrastructure includes:

- **Electricity supply**
  - ❖ **Power stations**: all three power stations are situated near the coastline. These are: (a) Moni power station, (b) Dhekelia power station and (c) Vasilikos power station.

  - ❖ **Energy center at Vasilikos**;
- **Water supply**
  - ❖ **Water treatment plants**. Major water plants are located near the shorelines (within less than a kilometer) such as the plants located at Limassol, Dhekelia, Khirokitia, and Tersephanou (Arku, 2009);
  - ❖ **Wastewater treatment plants**. The plants located in the shoreline of Cyprus are: Limassol, Larnaca, Paphos and Paralimni - Agia Napa. The first three are situated in low-land area while the last in higher elevation compared to sea level;
  - ❖ **Desalination plants**. Dhekelia and Larnaca plants; (see also Figure 13-6)
- **The international airport of Larnaca**. It must be noticed that Larnaca is the most low-lying region of Cyprus, rising concern over flood risk (EC, 2009);
- **Larnaca port**;
- **Marinas and fishing shelters**;
- **Industries.** Moni and Vassilikos cement plants, which are situated near Limassol;
- **Buildings.** The bulk of buildings situated in or near coastal areas are tourist accommodation units and in specific, the part of coastline dedicated to tourist activities is approximately 103 km while for residential only 17 km (see also Section 13.2.6.3). What is more, it must be noticed that the vast majority of tourist infrastructure is located near the coastline (~95%), pointing out the sensitivity of tourist economy to climate induced impacts related with flooding from sea on the sector.

To this end, the exposure of the sector to sea floods was ranked as **very high.**

Urban floods

In order to assess the exposure of the infrastructure to flood events it is essential to examine the changes in land use and their implications for flood risks.

According to the latest data available from the Water Development Department (WDD, 2011), over the last years there has been observed a significant increase in the building construction sector. More particularly, a steep increase can be noticed between 2003 and 2005, followed by a stable or slight downward trend (see Figure 13-13).

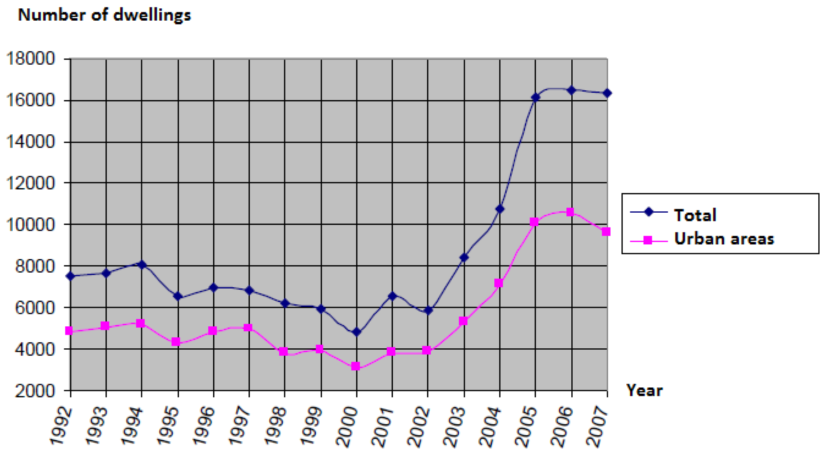


Figure 13-13: Number of dwellings constructed in the private sector between 1992 and 2007

Source: WDD, 2011

However, changes in land use persist over last years, especially in touristic areas such as Paralimni, where there have been observed remarkable changes from agricultural to residential land use (see Figure 13-14).

Land use changes can induce significant flood risk through changes in the runoff coefficient. Runoff coefficient which reflects the percentage of precipitation that appears as runoff, is affected from the ground cover of an area as different materials, such as different type of soils and concrete present different properties concerning water (e.g infiltration). Ground slope plays also an important role in estimating the runoff coefficient of an area.

For example, the runoff coefficient for an unimproved, undeveloped area may be in the order of 0.1 to 0.3, while the respective figure for a developed area may vary from 0.4 to 0.7. This fact implies the increased flood risk in urban centers and in areas with poor urban planning.

To this end, in order for a potential future flood event to be considered, the change in runoff coefficient must be evaluated, taking into account not only the current situation but also the prospects and future development trends of the particular area.


Figure 13-14: Land use change in the touristic area of Paralimni between April 2003 (on the left) and June 2010 (on the right).

Source: WDD, 2011

Taking into consideration the above points, the exposure of the sector to urban floods was ranked as **high**.

13.4.1.2 Assessment of adaptive capacity

In order to reduce the impact of floods, the Cyprus Government has undertaken a series of flood protective measures including but not limited to the following:

(a) Hard coastal defense works (*for sea flood protection*),
(b) Fishing shelters and artificial reefs (*for sea flood protection*),
(c) Dams (*for urban flood protection*)
(d) Sustainable Urban Drainage systems (*for urban flood protection*).

Sea Floods

Flood protection measures

(a) **Hard coastal defense works**

Hard engineering structures such as seawalls, coastal revetments and breakwaters, help prevent coastal flooding. However, seawalls and revetments are not considered attractive for bathing beaches where the tourism infrastructure is located and thus breakwaters and groynes are the predominant defense works, although the latter are considered less drastic measures in case of a severe storm or flooding event. For more information of the coastal defense works constructed in Cyprus, one may refer to Section 5.4.1: Coastal storm flooding and inundation.

(b) **Fishing shelters and artificial reefs** (*sea flood protection*).

Fishing shelters are constructed for the protection of fishing boats against extreme events such as storms and large waves, also provide for the protection of coastal infrastructure. Currently, there are eleven fishing shelters in operation in Cyprus.

Artificial reefs which are actually submerged breakwaters also provide protection from flooding by absorbing part of the incident wave energy before it reaches the coast. The DMFR will create up to 4 artificial reefs in the marine areas of Famagusta, Limassol and Paphos (Source: Strategy for the creation of artificial reefs, Cyprus).

Land uplift of Cyprus

For the case of Cyprus there are no available data which indicate that there will be an increase in relevant extreme events. More significantly, even if Sea Level Rise (SLR) in Cyprus was expected to be moderate (between 5 and 10 mm/year), this is not likely to arise in the coming years. According to research studies (EC, 2009; Nicholls & Hoozemans, 1996), Cyprus is experiencing a land lift-up[79], something that shall offset at a certain degree a potential sea level rise.

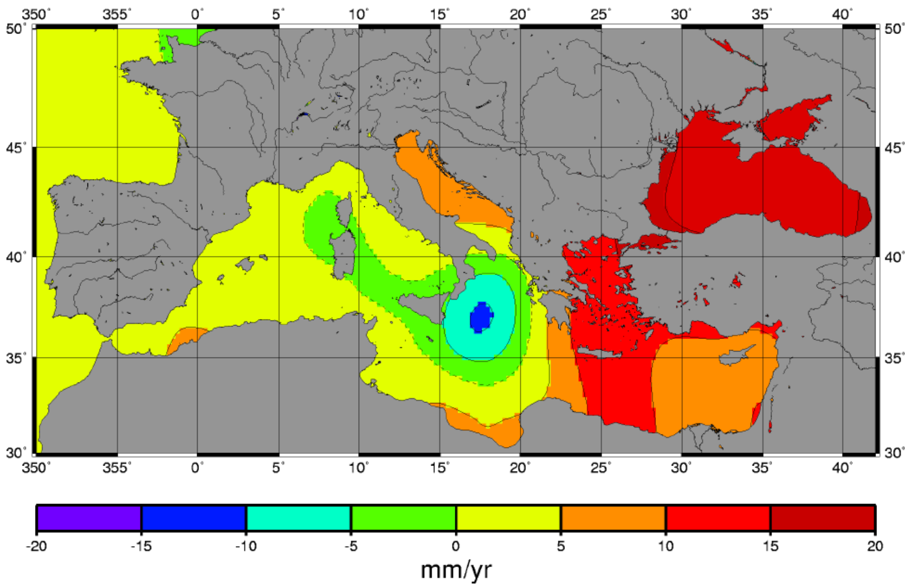


Figure 13-15: Mediterranean Sea level changes as observed during the period between 1993 and 2000

Source: MoE, 2011

[79] According to Nicholls & Hoozemans (1996), the rate of land lift-up is estimated at 0 - 1mm/year.

Taking everything into account, the adaptive capacity for sea floods was ranked as **limited** to **moderate**.

Urban floods

Flood protection measures

(c) Dams

The purpose of building a dam is not limited to water supply but also for flood risk minimization, as its storage contributes to the attenuation of flood peaks.

According to the detailed river basin management plan (Annex I) of the Water Development Department (WDD, 2011b), 36 out of the 107 constructed dams in Cyprus are designed for flood risk minimization.

Moreover, they have been designed according to high flood protection standards (1 to 500 or 1 to 1000 chance of flooding).

It is stressed that even if dams do not comprise vulnerable infrastructure, their monitoring is considered of particular importance as they may induce safety risks.

(d) Sustainable Urban Drainage Systems

Regarding urban floods, the Cyprus government has taken measures for the reduction of urban flood risks, by developing Sustainable Urban Drainage Systems (SUDS). When referring to these systems, it must be noticed that they comprise stormwater retention ponds which are used both for flood protection and for aquifer recharge. In Cyprus, such systems have been installed at Limassol and Paralimni. Finally, Paphos has been identified as a suitable area for the implementation of SUDS (WDD, 2009).

What is more, the complete separation of the sewerage and drainage system is underway, as the latter is being expanded in most urban centers, providing therefore the basis for reducing to a large degree the flooding risk of the sewerage system.

Taking everything into account, the adaptive capacity for urban floods was considered to be **moderate**.

13.4.2 Damages of infrastructure due to landslide damage

13.4.2.1 Assessment of sensitivity and exposure

Sensitivity: It is expected that climate change shall not affect significantly ground stability and thus minor impact is expected regarding the occurrence of landslides due to climate change. In this regard the sensitivity was ranked as **limited**.

Exposure: - (**No data)**

According to the Geological Survey Department of Cyprus, there has never been conducted a complete survey regarding the risk for landslides in Cyprus. To this end, it must be stressed that further work has to be done in order to obtain a clear and certain picture on the topic.

However, there have been observed a number of landslide events and instability problems in the area of Pafos.

13.4.2.2 Assessment of adaptive capacity

Given the serious risk of landslides[80], GSD has undertaken a research project entitled 'Study of landslides in areas of Pafos District', the main purpose being to promote a more efficient and secure urban development. It must be emphasized that it is appropriate such studies to be elaborated in order to allow the adaptive capacity to increase.

Also, few landslide protection measures have been undertaken such as road protection measures, retention walls and terraces.

To this end, the adaptive capacity is ranked as **limited**.

[80] It has been recorded that some villages have been relocated to safer places in the past

13.4.3 Assessment of overall vulnerability

The principal aim of this chapter is to identify the key vulnerabilities of the infrastructure sector to climate changes, as well as to assess the magnitude of these vulnerabilities. However, it must be noted that, as there were no sufficient data to evaluate all indicators further research is required.

In order to quantify the vulnerability potential of the infrastructure sector against a climatic change impact, the values of sensitivity, exposure, adaptive capacity and vulnerability are quantified as follows:

Degree of sensitivity, exposure & adaptive capacity		Degree of vulnerability		Legend
None	0	None	V≤0	
Limited	1	Limited	0<V≤1	
Limited to Moderate	2	Limited to Moderate	1<V≤2	
Moderate	3	Moderate	2<V≤3	
Moderate to High	4	Moderate to High	3<V≤4	
High	5	High	4<V≤5	
High to Very high	6	High to Very high	5<V≤6	
Very high	7	Very high	6<V≤7	
Not evaluated	-	Not evaluated	-	

Since vulnerability is defined by the following formula:

$$Vulnerability = Impact - Adaptive\ capacity$$

$$where\ Impact = Sensitivity * Exposure$$

“Impacts” and “Adaptive capacity” should be evaluated on the same scale (1-7). For this to be achieved, the square root of “Sensitivity x Exposure” is used. The results of the vulnerability assessment for the infrastructure sector in Cyprus are summarized in Table 13-9.

Table 13-9: Overall vulnerability assessment of the infrastructure sector in Cyprus to climate changes

Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Damage from urban floods	Moderate to High (4)	High (5)	Moderate (3)	Limited to Moderate (1.5)
Damage from sea floods	Limited (1)	Very High	Limited to Moderate (2)	Limited (0.7)
Damage from landslides	Limited (1)	Not evaluated	Limited (1)	-

In general, the infrastructures in Cyprus are not considered very vulnerable to climate changes. In specific, the first vulnerability priority of the sector to climate changes is related to the damages caused by urban floods. However, it must be noticed that specific measures have been undertaken in order to reduce the severity of this impact (drainage works, SUDS etc.). The second vulnerability priority is related to the damages to infrastructure caused by sea floods. Considering that a great number of infrastructures important for Cyprus is located in the coastal areas of the island and that Cyprus has not experienced any severe floods from the sea in the past, the vulnerability towards this impact is considered limited. The vulnerability of infrastructure systems to landslide cannot be evaluated due to limited availability of data.

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ANNEX I

Annex I: Vulnerability scores

Sector	Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Soils	Desertification	Very high (7)	Very high (7)	Limited to Moderate (2)	High (5.0)
Water resources	Water availability for irrigation	Very high (7)	Very high (7)	Limited to Moderate (2)	High (5.0)
Water resources	Droughts	Very high (7)	Very high (7)	Limited to Moderate (2)	High (5.0)
Water resources	Groundwater quality	High to Very high (6)	High to Very high (6)	Limited to Moderate (2)	Moderate to High (4.0)
Forests	Dieback of tree species, insect attacks and diseases	High to Very high (6)	High to Very high (6)	Limited to Moderate (2)	Moderate to High (4.0)
Agriculture	Crop yield	Very high (7)	High (5)	Limited to Moderate (2)	Moderate to High (3.9)
Tourism	Warmer summers	High to Very high (6)	High to Very high (6)	Moderate (3)	Moderate (3.0)
Biodiversity	Distribution of animal species in terrestrial ecosystems	High (5)	High (5)	Limited to Moderate (2)	Moderate (3.0)
Biodiversity	Distribution of plant species in terrestrial ecosystems	High (5)	High (5)	Limited to Moderate (2)	Moderate (3.0)
Forests	Fires	High to Very high (6)	High to Very high (6)	Moderate (3)	Moderate (3.0)
Coastal zones	Coastal Erosion	High (5)	High to Very high (6)	Moderate (3)	Moderate (2.5)
Soils	Soil Erosion (by wind and/or rain water)	Moderate to High (4)	High (5)	Limited to Moderate (2)	Moderate (2,5)
Agriculture	Damages to crops from extreme weather events	High (5)	Moderate to High (4)	Limited to Moderate (2)	Moderate (2.5)
Public health	Deaths and health problems related to heat waves and high temperatures	High (5)	Moderate to High (4)	Limited to moderate (2)	Moderate (2.5)
Tourism	Water availability	High (5)	High (5)	Moderate (3)	Limited to Moderate (2.0)
Water resources	Water availability for domestic water supply	Very high (7)	Very high (7)	High (5)	Limited to Moderate (2.0)

Sector	Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Energy	Energy demand for cooling and heating	Very High (7)	Very High (7)	High (5)	Limited to Moderate (2.0)
Tourism	Heat waves	High to Very high (6)	Moderate to High (4)	Moderate (3)	Limited to Moderate (1.9)
Agriculture	Soil fertility	Moderate (3)	High (5)	Limited to Moderate (2)	Limited to Moderate (1.9)
Infrastructure	Damages from urban floods	Moderate to High (4)	High (5)	Moderate (3)	Limited to moderate (1.5)
Soils	Soil Salinization - Sodification	Moderate to High (4)	Moderate (3)	Limited to Moderate (2)	Limited to Moderate (1.5)
Tourism	Coastal erosion	High to Very high (6)	Moderate (3)	Moderate (3)	Limited to Moderate (1.2)
Biodiversity	Freshwater biodiversity	High to Very High (6)	Moderate (3)	Moderate (3)	Limited to Moderate (1.2)
Biodiversity	Marine biodiversity	Moderate (3)	High to Very High (6)	Moderate (3)	Limited to Moderate (1.2)
Infrastructure	Damages from sea floods	Limited (1)	Very High (7)	Limited to moderate (2)	Limited (0.7)
Water resources	Floods	Moderate (3)	Moderate to High (4)	Moderate (3)	Limited (0.5)
Coastal zones	Coastal storm flooding and inundation	Moderate (3)	Limited to Moderate (2)	Limited to Moderate (2)	Limited (0.5)
Energy	Efficiency of thermal power plants	Limited (1)	Limited to Moderate (2)	Limited (1)	Limited (0.4)
Public health	Air pollution -related diseases	Moderate (3)	Moderate (3)	Moderate (3)	None (0.0)
Tourism	Storms, waves and floods	High to Very high (6)	Moderate (3)	Moderate to high (4)	Limited (0,2)
Water resources	Surface water quality	Moderate to High (4)	Limited to Moderate (2)	Moderate (3)	None (-0.2)
Public health	Deaths and injuries from floods/storms	Limited to moderate (2)	Moderate (3)	Moderate (3)	None (-0.6)
Public health	Fire- related deaths and injuries	Moderate (3)	Limited to moderate (2)	Moderate (3)	None (-0.6)

Sector	Impact	Sensitivity	Exposure	Adaptive Capacity	Vulnerability
Soils	Landslides	Moderate (3)	Limited to Moderate (2)	Moderate (3)	None (-0.6)
Tourism	Biodiversity attractions	Limited (1)	Limited to Moderate (2)	Limited to Moderate (2)	None (-0.6)
Energy	Renewable energy yield (other than hydropower)	Limited to Moderate (2)	Limited (1)	Limited to Moderate (2)	None (-0.6)
Soils	Soil contamination	Limited (1)	Moderate (3)	Moderate (3)	None (-1.3)
Public health	Vector-borne and rodent-borne diseases	Limited (1)	Limited to moderate (2)	Moderate (3)	None (-1.6)
Public health	Landslide- related deaths and injuries	Limited to moderate (2)	Limited (1)	Moderate (3)	None (-1.6)
Public health	Water/Food-borne diseases	Limited (1)	Limited to moderate (2)	Moderate to High (4)	None (-2.6)
Tourism	Warmer winters	Limited (1)	Limited (1)	Moderate to High (4)	None (-3.0)
Public health	Climate-related effects upon nutrition	Moderate (3)	Limited (1)	High (5)	None (-3.3)
Forests	Floods	Limited (1)	Limited (1)	High (5)	None (-4.0)
Coastal zones	Degradation of Coastal Ecosystems	Moderate to High (4)	Not evaluated	Not evaluated	Not evaluated
Agriculture	Pest and diseases	Not evaluated	Not evaluated	Not evaluated	Not evaluated
Fisheries	Fishstock physical environment	Not evaluated	Not evaluated	Limited to Moderate (2)	Not evaluated
Fisheries	Cost implications for fishermen	Not evaluated	Not evaluated	Limited (1)	Not evaluated
Fisheries	Quantity and diversity of fishstocks	Not evaluated	Not evaluated	Limited to Moderate (2)	Not evaluated
Forests	Forest growth	Not evaluated	Not evaluated	Limited to moderate (2)	Not evaluated
Infrastructure	Damages from landslides	Limited (1)	Not evaluated	Limited (1)	Not evaluated
Agriculture	Livestock productivity	Not evaluated	Not evaluated	Not evaluated	Not evaluated
Agriculture	Costs for livestock catering	Not evaluated	Not evaluated	Not evaluated	Not evaluated