Cyprus International Institute

Harvard School of Public Health

Impacts of Climate Change on Cyprus Water Supply, Agriculture, and Biodiversity

Adaptation and Mitigation Measures

Students name: Andreou Evangelia - Biodiversity
Constantinou Irene - Agriculture
Ierodiakonou Despo – Introduction & Adaptation and Mitigation Measures
Stefanou Charalambos – Water Resources

1. Introduction

Climate change is considered one of the most complicated global issues humanity is facing today. Since 1970, many studies and data sets have indicated the observed trends in the physical and biological environment and their relationship to regional climate change (UNEP, 2007). The recent assessment of the Working Group II of the Intergovernmental Panel on Climate Change (IPCC) concluded that “there is high confidence that recent regional changes in temperature have had discernible impacts on many physical and biological systems”. Examples of changes in natural ecosystems include:

- Increasing ground instability in permafrost regions and changes in some Arctic and Antarctic ecosystems.
- Warming of lakes and rivers in many regions with effects on thermal structure and water quality.
- Observed changes in marine and freshwater biological systems associated with rising water temperature.

According to the IPCC report (4th Assessment), much evidence gathered over the past 5 years that indicate changes in many physical and biological changes which are linked to anthropogenic warming. This evidence is concentrated on the following:

- An assessment by the IPCC group that the observed increase in global average temperature is likely due to greenhouse gas concentrations.
- 29,000 observational data sets from 75 studies showed significant change in many physical and biological systems – of which 89% of them were linked with changes in climate conditions.
- A spatial agreement between regions of significant global warming and changes of systems.
- Several modelling studies have linked physical and biological changes to anthropogenic warming.

In Europe, for the first time scientists have documented profound impacts of changes in the current climate conditions: retreating glaciers, longer growing seasons, shift of species and health impacts due to extreme weather conditions, for example heat waves.

Northern Europe has been negatively affected by climate change, causing major challenges to many economic sectors. Negative impacts include increased inland flash floods, more frequent coastal flooding and erosion, which related impacts to the ecosystems of these areas. Also, glacier retreat and reduced snow cover and winter have caused serious threats to species and high erosion issues.

In the southern part of Europe, climate change has caused some major problems after already experiencing worsening of climatic conditions such as higher temperatures and long periods of drought. This area is already quite vulnerable to changes in water and climate patterns, and these emerging changes have caused serious environmental, economic and social problems.

Cyprus is a small island located at the south-eastern side of the Mediterranean. Climate change has its toll to the island, in a variety of areas. Decrease of water supply due to a constant decease in precipitation has caused major water shortage problems. This in combination with the fact that the island has experienced long periods of drought, and had to deal with a steady increase in demand for water, have considerably reduced the water resources.

Cyprus has also experienced serious coastal erosion problems, with effects to local resources such as fishing. Deforestation and desertification are also major stressors to Cyprus, with serious consequences to the natural resources of the island, affecting almost every economic aspect.

Sea level rise is another phenomenon that is projected to hit the island with major consequences in the loss of land, the salination of water sources, the increase in erosion and coastal hazards, threatening important infrastructure of the island such as airports, power plants, desalination plants, water treatment systems and almost all tourist activities of the country.

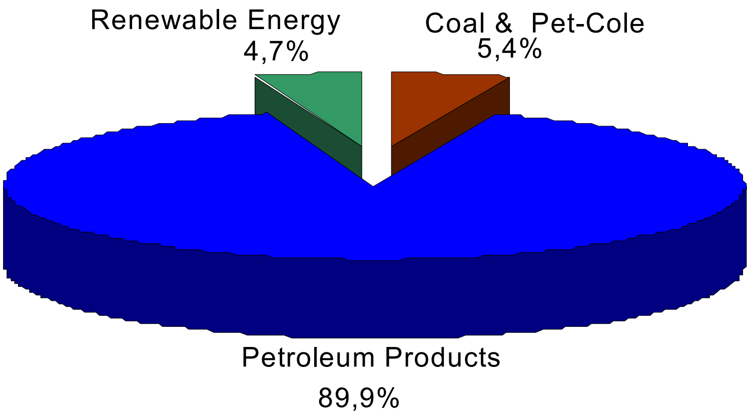
Last, by increasing temperatures, there is an increased threat for an invasion by exotic, non-native species that can easily adapt to the new climate conditions and threat the balance of the natural ecosystems.

Cyprus does not have any greenhouse gas emission reduction or limitation obligations under the Kyoto Protocol EU legislation. However, Cyprus is taking concrete steps to reduce its emissions of greenhouse gases, which up to 2003 were quite high relative to average EU 25 levels. Accordingly, a number of demand side measures (energy efficiency) and supply side measures (renewable energy) are already being affected.

Specifically, Cyprus's stated target under the EU legislation on the promotion of electricity production from renewable energy sources is to generate 6% of its electricity from renewable energy sources by 2010. A number of measures and incentives are in place to promote investment in renewable energy technologies including wind power, biomass and solar photovoltaic, presented in the energy section of the report. These measures are already generating substantial interest, and it is clear that the contribution of renewables will increase over the next years.

Furthermore, there are plans to establish an Energy Centre that will provide Liquefied Natural Gas (LNG) as a major fuel in Cyprus for the first time especially for the production of electricity. It is planned to have the Energy Centre operational by 2010. (www.moa.gov.cy).

The current situation in Cyprus regarding energy use is as follows (National Sustainable Development Strategy, 2006):



It is apparent that energy is Cyprus is totally dependent on fossil fuels (89.9%), with coal only producing 5.4% of energy and renewable resources, basically solar energy producing 4.7% of total energy for the island. Consequently, greenhouse gas emissions for Cyprus at for the base year (1990) and predictions up to 2020 are as follows:

Development of greenhouse gases emissions (kt CO_2-equiv)

	1990	**2010**	**2015**	**2020**
Energy	4452.9	10689.8	12539.7	15175.4
Industrial Procedures	570.6	646.5	686.1	665.7
Solvents	2.3	3.0	3.0	3.0
Agriculture	570.6	739.0	741.1	741.1
Waste	433.2	632.1	657.3	638.4
TOTAL	**6029.6**	**12710.4**	**14627.2**	**17223.6**

Source: National Sustainable Development Strategy, 2006.

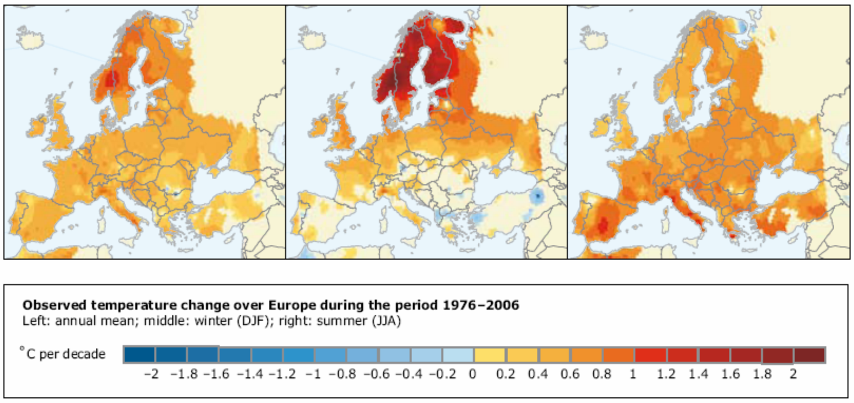
2. Impacts of Climate Change to Water Resources

Water is essential to life and is an indispensable resource for nearly all human activity. It is intricately linked with climate change through a large number of connections and feedback cycles, so that any alteration in the climate system will induce changes in the hydrological cycle. Global warming not only results in widespread melting of snow and ice, but also augments the water-holding capacity of the air and amplifies evaporation. This leads to larger amounts of moisture in the air, an increased intensity of water cycling and changes in the distribution, frequency and intensity of precipitation. Consequently, the distribution in time and space of freshwater resources, as well as any socio‑economic activity depending thereon, is affected by climate variability and climate change.

All regions of the world show an overall net negative impact of climate change on water resources and freshwater ecosystems. Areas in which runoff is projected to decline are likely to face a reduction in the value of the services provided by water resources. The beneficial impacts of increased annual runoff in other areas are likely to be tempered in some areas by negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risks (IPCC, 2007). There is growing evidence for changes in the global hydrological cycle over the past 50 years that may be linked to changes in climate, such as an increasing continental runoff, a wetter northern Europe and a drier Mediterranean, an increase in the intensity of extreme precipitation events over many land regions, and changes in the seasonality of river flows where winter precipitation dominantly falls as snow.

2.1. European Temperature

Map 5.1 Observed temperature change over Europe 1976–2006



Observed temperature change over Europe during the period 1976–2006
Left: annual mean; middle: winter (DJF); right: summer (JJA)

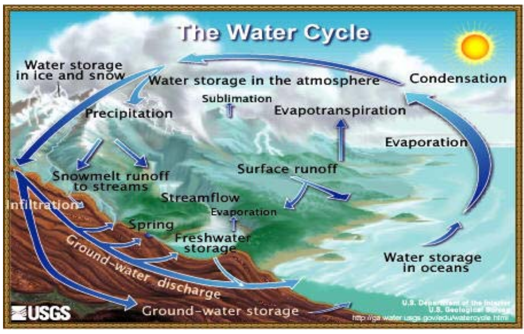
Source: The climate dataset is from the EU-FP6 project ENSEMBLES (http://www.ensembles-eu.org) and the data providers in the ECA&D project (http://eca.knmi.nl).

The global (land and ocean) average temperature up to 2007 was 0.8 °C higher than pre‑industrial levels (1850–1899 average). For land only, the average was 1 °C higher. The rate of increase of global average temperature has increased from 0.1 °C per decade over the past 100 years to 0.2 °C per decade in the past decade. The best estimates for projected global warming during this century are a further rise in average temperature of between 1.8 and 4.0 °C for different scenarios that assume no further/additional action to limit emissions. Europe has warmed more than the global average. The annual average temperature for the European land area up to 2007 was 1.2 °C above pre‑industrial levels, and for the combined land and ocean area 1 °C above. Eight of the 12 years between 1996 and 2007 were among the 12 warmest years since 1850. The annual average temperature is projected to rise this century by 1–5.5 °C (best estimate) with the largest warming over eastern and northern Europe in winter, and over south-western and Mediterranean Europe in summer.

2.2. Water Availability

The movement of water between the land surface, oceans and atmosphere is called the hydrologic cycle. Water in the atmosphere is transported to the land surface and oceans as precipitation (rain, snow or sleet). Upon reaching the land surface, water may immediately become stream flow, or it may infiltrate into the soil where it may later be taken up by plants or it can percolate to the groundwater. Surface stream flow and groundwater flow move water from the land surface to lakes and the ocean. Water re-enters the atmosphere as vapor either via evaporation from surface waters (ocean, lakes, etc) or transpiration from plants. This cyclical movement of water is driven by solar energy. An increase in net solar radiation or temperature will effectively speed up the processes within this cycle (evaporation, condensation, precipitation, etc). Due to complex interactions of changes in the hydrologic cycle with global circulation patterns and local weather patterns, an increase in energy in the hydrologic cycle does not necessarily translate into an increase in precipitation in all geographic regions. It is difficult to predict future changes in regional precipitation patterns. Predicting regional changes in stream flow and groundwater recharge due to climate change also remains challenging, particularly because of the uncertainty in regional projections of how precipitation may change (IPCC, 2007).

Changes in temperature, precipitation patterns and snowmelt can have impacts on water availability. Temperature is predicted to rise in most areas, but is generally expected to increase more in inland areas and at higher latitudes. Higher temperatures will increase loss of water through evaporation. The net impact on water supplies will depend on changes in precipitation (including changes in the total amount, form, and seasonal timing of precipitation). Generally speaking, in areas where precipitation increases sufficiently, net water supplies may not be affected or they may even increase. In other areas where precipitation remains the same or decreases, net water supplies would decrease. Where water supplies decrease, there is also likely to be an increase in demand, which could be particularly significant for agriculture (the largest consumer of water) and also for municipal, industrial and other uses. Increases in temperature can affect the amount and duration of snow cover which, in turn, can affect timing of stream flow. Glaciers are expected to continue retreating, and many small glaciers may disappear entirely. Peak stream flow may move from late spring to early spring/late winter in those areas where snow pack is important in determining water availability. Changes in stream flow have important implications for water and flood management, irrigation, and planning. If supplies are reduced, off-stream users of water, such as irrigated agriculture and in-stream users such as hydropower, fisheries, recreation and navigation, could be most directly affected (IPCC, 2007).



Source:

http://ga.water.usgs.gov/edu/watercyclesummary.html

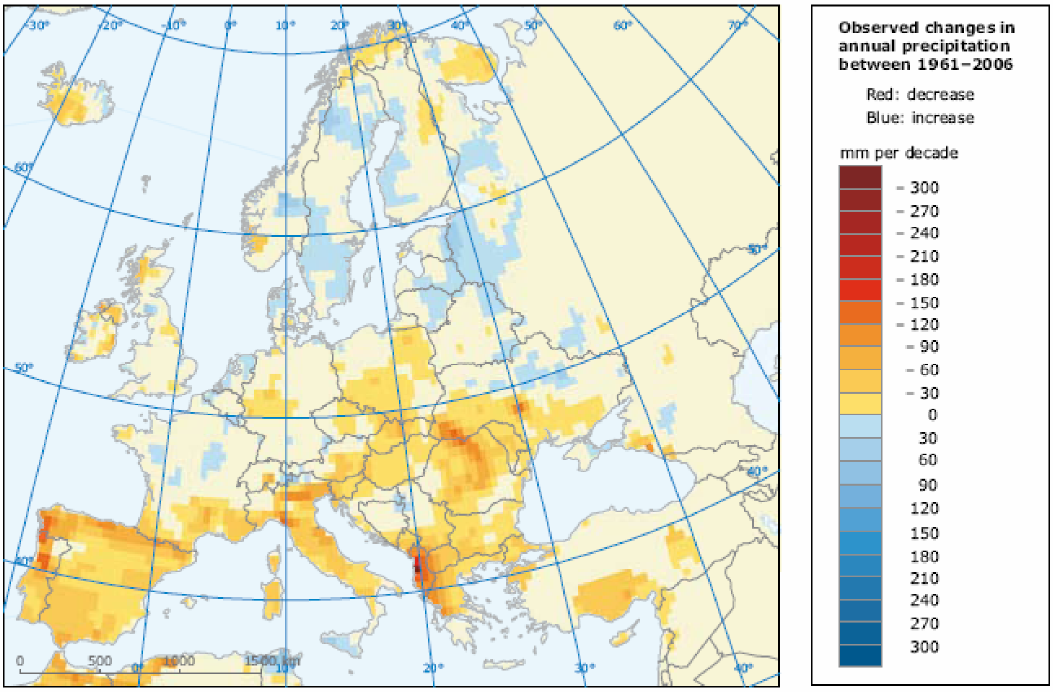
2.3. Water Quality

Higher water temperatures and changes in the timing, intensity, and duration of precipitation can affect water quality. Higher temperatures reduce dissolved oxygen levels, which can have an effect on aquatic life. Where stream flow and lake levels fall, there will be less dilution of pollutants; however, increased frequency and intensity of rainfall will produce more pollution and sedimentation due to runoff (IPCC, 2007). Flood magnitudes and frequencies will very likely increase in most regions, mainly a result of increased precipitation intensity and variability and increasing temperatures are expected to intensify the climate's hydrologic cycle and melt snow packs more rapidly (IPCC, 2007). Flooding can affect water quality, as large volumes of water can transport contaminants into water bodies and also overload storm and wastewater systems. Higher temperatures, particularly in the summer, earlier snowmelt, and potential decreases in summer precipitation could increase risk of drought. The frequency and intensity of floods and droughts could increase, even in the same areas. Sea level rise may also affect freshwater quality by increasing the salinity of coastal rivers and bays and causing saltwater intrusion, movement of saline water into fresh ground water resources in coastal regions. Changes in water quality could have implications for all types of uses. For example, higher temperatures and changes in water supply and quality could affect recreational use of lakes and rivers or productivity of freshwater fisheries. Certain species of fish could find temperatures too warm and migrate to more northern or higher altitude locations where water is cooler.

2.4. Impacts of Europe's Changing Climate

2.4.1. Precipitation and Droughts

Map 5.4 **Observed changes in annual precipitation 1961–2006**



Note: Data are in mm per decade, blue means an increase, red a decrease. The observations indicate that large decadal scale variability in precipitation amount is superposed on the long time scale trends described above. This variability is partly related to the decadal scale variability in atmospheric circulation anomalies (see Box 5.1). Calculating trends over shorter time periods may therefore lead to different results. The yellow color indicates that the trend 1961–2006 is not significant at level 25 %.

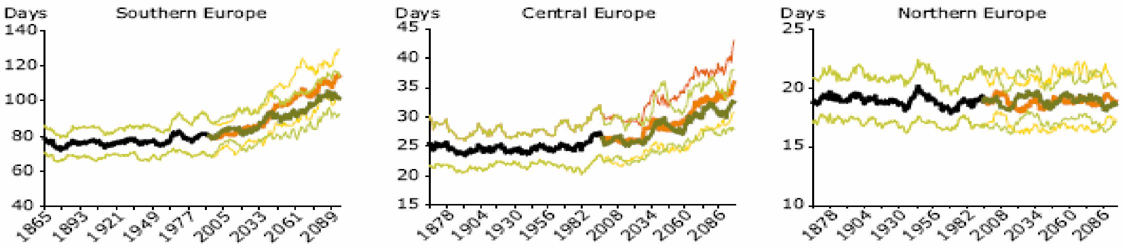
Source: The climate dataset is from the EU-FP6 project ENSEMBLES (http://www.ensembles-eu.org) and the data providers in the ECA&D project (http://eca.knmi.nl).

Annual precipitation trends in the 20th century showed an increase in northern Europe (10–40 %) and a decrease in some parts of southern Europe (up to 20 %). Mean winter precipitation has increased in most of western and northern Europe (20 to 40 %), whereas southern Europe and parts of central Europe were characterized by drier winters. Seasonally, models project a large-scale increase in winter precipitation in mid and northern Europe. Many parts of Europe are projected to experience dryer summers. Relatively small precipitation changes are projected for spring and autumn (Räisänen *et al.*, 2004; Kjellström, 2004). But there are uncertainties in the magnitude and geographical details of the changes. For Europe as a whole, the intensity of precipitation extremes such as heavy rain events has increased in the past 50 years, even for areas with a decrease in mean precipitation such as central Europe and the Mediterranean. The proportion of Europe experiencing meteorological drought conditions did not change significantly during the 20th century. For Europe as whole, heavy precipitation events are projected to continue to become more frequent. Dry periods are projected to increase in length and frequency, especially in southern Europe. Both high and low precipitation extremes (high intensity or long lasting rain and droughts, respectively) can lead to periods with a high amount of total precipitation or with precipitation deficit. The periods can range from minutes (e.g. in case of intense showers) to days, weeks or even months (with long lasting rain events or absence of precipitation). High precipitation extremes can result in fast flash floods, sewerage system failure and land‧slides, or devastating floods, affecting large catchments and having longer duration. Low precipitation extremes can lead to droughts. Drought is a natural phenomenon, defined as sustained and extensive occurrence of below average water availability. Drought should not be confused with aridity, which is a long-term average feature of a dry climate. Nevertheless, the most severe human consequences of drought can be found in arid regions, where water availability is naturally lower. Likewise, drought should not be confused with water scarcity, which reflects conditions of long-term imbalances, between water supply and demands (e.g. van Lannen *et al.*, 2007). Droughts can affect both high and low rainfall areas of Europe and can develop over short periods of weeks and months or much longer periods of several seasons, years and even decades. In many cases drought develops gradually, making it difficult to identify and predict. Precipitation is the primary factor controlling the origin and persistence of drought conditions for all types of drought. The most common definitions and types of drought are:

- Meteorological drought: departure of precipitation from normal values for an extended period of time, the primary cause of the other types of drought.
- Hydrological drought: deficiencies in surface and subsurface water supplies, reflecting effects and impacts of meteorological droughts.
- Agricultural drought: a deficit of soil moisture affecting a particular crop at a particular time.
- Socio‧economic drought: imbalance between supply and demand for an economic good, capturing both drought condition and human activities.

The combination of higher temperatures and reduced mean summer precipitation is expected to enhance the frequency and intensity of droughts across Europe. This can be illustrated, for example, by the projected number of consecutive dry days, defined as days with precipitation below 1 mm (Figure 5.5). In southern Europe, the maximum number of these days is projected to increase substantially during the 21st century. The longest dry period within a year may be prolonged here by one month at the end of 21st century. In central Europe, prolongation of longest dry period is by one week, and no prolongation is projected for northern Europe. Thus regions in Europe that are now dry are projected to become even more vulnerable. Climate projections indicate that in warmer conditions droughts may become longer-lasting and more severe in current drought-prone regions because of decreased rainfall and enhanced evaporation. The impacts of droughts on people and the environment result from a combination of the intensity and duration of drought events and the vulnerability of agricultural or water resources systems, including water management policies, the characteristics of regional and local water infrastructure, and social responses to drought situations. Drought is a phenomenon that is not constrained by international boundaries and can therefore grow to afflict many countries simultaneously and may stress relationships between them.

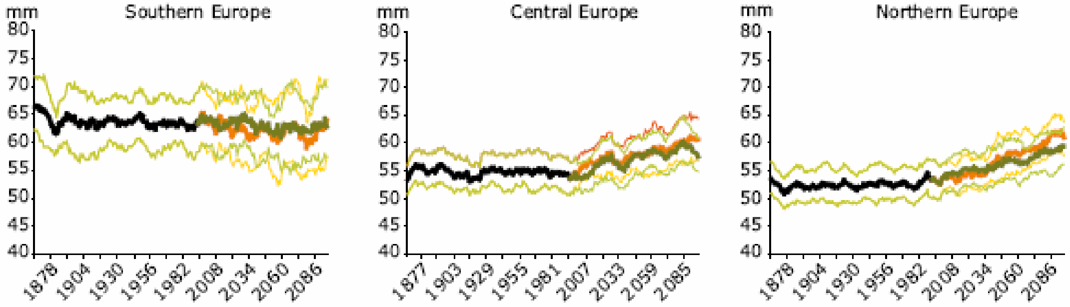
Figure 5.5 Simulated land average maximum number of consecutive dry days for different European regions (1860–2100)



Note: The 20th century (black), models simulations for IPCC SRES intermediate A1B (orange) and low B1 (green) emission scenarios. The respective ensemble means are displayed. The minimum and maximum of the ensemble members are indicated by thin green (B1) and yellow (A1B), respectively. Data are smoothed by 10-year running means.

Source: Sillmann and Roeckner, 2008.

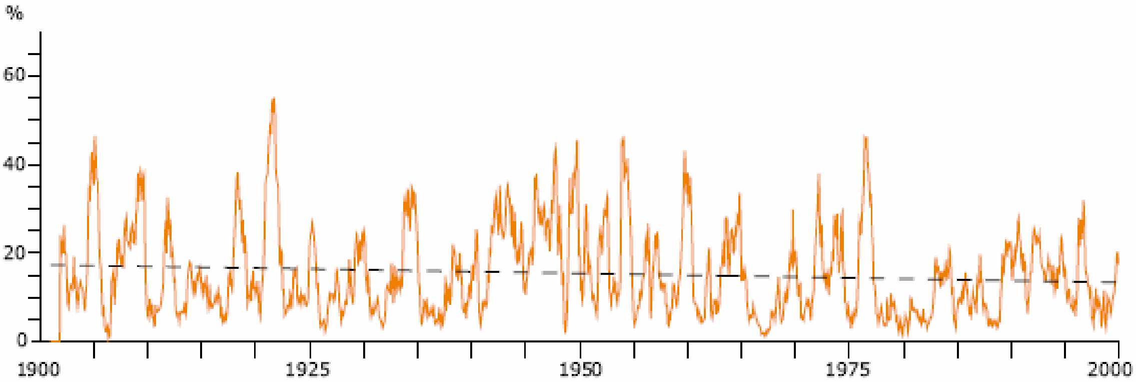
Figure 5.4 Simulated land average maximum 5-day total precipitation for different European regions (1860–2100)



Note: The 20th century (black), models simulations for IPCC SRES intermediate A1B (orange) and low B1 (green) emission scenarios. The respective ensemble means are displayed. The minimum and maximum of the ensemble members are indicated by thin green (B1) and yellow (A1B), respectively. Data are smoothed by 10-year running means.

Source: Sillmann and Roeckner, 2008.

Figure 5.3 Percentage of Europe experiencing moderate drought conditions during the 20th century



Note: Expressed as standardized precipitation indices (SPI) for time scales of 12 months. The dashed line shows the linear trend. Errors are ± 2 standard errors in the gradient.

Source: Lloyd-Hughes and Saunders, 2002.

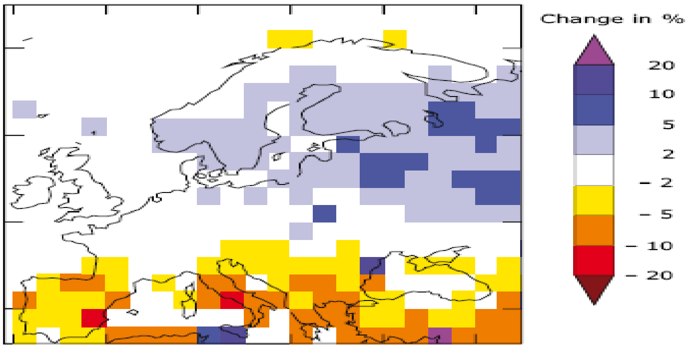
2.4.2. River Flow, Floods and Droughts

From a resource perspective, river flow is a measure of sustainable fresh water availability in a basin. Variations in river flow are determined mainly by the seasonality of precipitation and temperature, as well as by catchment characteristics such as geology, soils and land cover. River flow can be used as an indicator because changes in global warming modify the distribution of water at the land surface, and consequently the annual water budget of river basins as well as the timing and seasonality of river flows. The consequent changes in water availability may adversely affect ecosystems and several socio-economic sectors such as water management, energy production, navigation, irrigation and tourism. In view of projected global warming and the associated changes in water availability, it will become increasingly important to balance competing societal, industrial, agricultural and environmental demands. Sustainable options for mitigating the effects of changes in water availability include improved water efficiency, the re-use of water, and metering and water pricing to stimulate awareness and encourage water conservation. In accordance with the observed changes in precipitation and temperature, there is some evidence for climate-induced changes in annual river flow, as well as in the seasonality of flow, in Europe during the 20th century.

However, anthropogenic interventions in the catchment, such as groundwater abstraction, irrigation, river regulation, land use changes and urbanization, have considerably altered river flow regimes in large parts of Europe, confounding climate change detection studies. In northern parts of Europe, mean annual river flow has in general increased (Lindström and Bergström, 2004; Milly *et al.*, 2005). Increases occurred mainly in winter and spring (Hisdal *et al.*, 2007), probably caused by a general temperature increase during recent decades in combination with increased winter precipitation in the northern regions. Significant increases in river flow have also been observed in Scotland at one third of the river gauging stations in the past three decades (Werritty, 2002), as well as in winter and autumn in western Britain, consistent with recent increases in winter rainfall and a positive North Atlantic Oscillation index (Dixon *et al.*,2006).

However, some of these changes could be part of natural variability (Wade *et al.*, 2005). In western and central Europe, annual and monthly mean river flow series appear to have been stationary over the 20th century (Wang *et al.*, 2005). In mountainous regions of central Europe, however, the main identified trends are an increase in annual river flow due to increases in winter, spring and autumn river flow. In summer, both upward and downward trends have been detected (Birsan *et al.*, 2005). In southern parts of Europe, a slightly decreasing trend in annual river flow has been observed (Milly *et al.*, 2005). Annual river flow is projected to decrease in southern and south-eastern Europe and increase in northern Europe, but absolute changes remain uncertain. Climate change is projected to result in strong changes in the seasonality of river flows across Europe. Summer flows are projected to decrease in most of Europe, also in regions where annual flows will increase. Regions in southern Europe which already suffer most from water stress are projected to be particularly vulnerable to reductions in water resources due to climate change. This will result in increased competition for available resources.

Map 5.22 **Modelled change in annual river flow between 1971–1998 and 1900–1970**

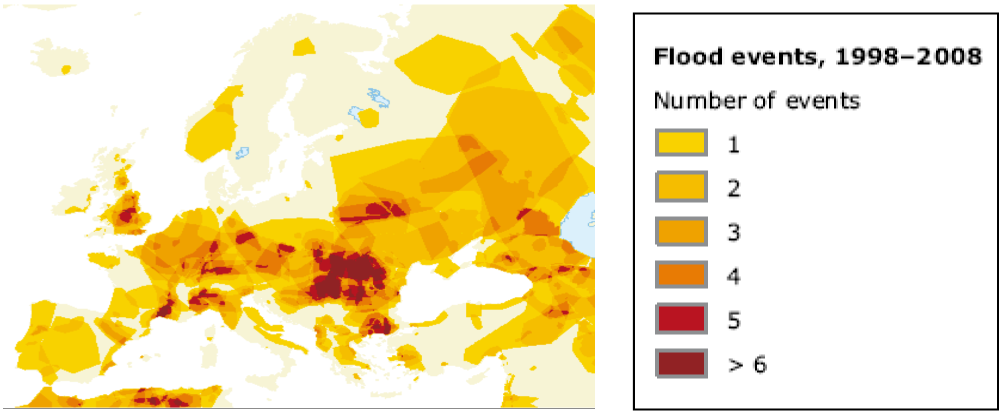


Note: The map is based on an ensemble of 12 climate models and validated against observed river flows.

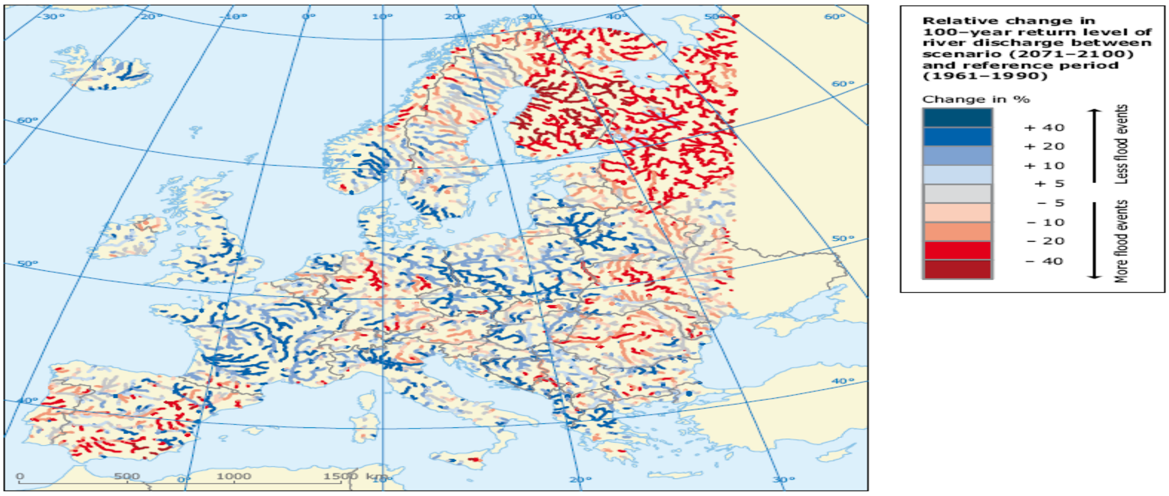
Source: Milly *et al.*, 2005.

There are different types of floods, such as large-scale river floods, flash floods, ice-jam and snowmelt-induced floods, and coastal floods due to sea-level rise. Inland river floods are linked mainly to prolonged or heavy precipitation events or snowmelt, hence are suitable indicators of climate change. River floods are the most common natural disaster in Europe. They can result in huge economic losses due to damage to infrastructure, property and agricultural land, and indirect losses in or beyond the flooded areas, such as production losses caused by damaged stock or roads, or the interruption of power generation and navigation. They can lead to loss of life, especially in the case of flash floods, and displacement of people, and can have adverse effects on human health and the environment. Procedures for designing flood-control infrastructures will have to be revised if they are to cope with the projected changes in extreme precipitation and river flows. Flood management policy will have to shift from defensive action towards the management of risk and enhancing the ability of societies to live with floods. This can be achieved by the use of non‑structural flood protection measures such as spatial planning, early warning, relief and post-flood recovery systems, as well as flood insurance (Kundzewicz *et al.*, 2002).

Although a significant trend in extreme river flows has not yet been observed, twice as many river flow maxima occurred in Europe between 1981 and 2000 than between 1961 and 1980. Since 1990, 259 major river floods have been reported in Europe, of which 165 have been reported since 2000. The rise in the reported number of flood events over recent decades results mainly from better reporting and land-use changes. Nevertheless, global warming is projected to intensify the hydrological cycle and increase the occurrence and frequency of flood events in large parts of Europe, although estimates of changes in flood frequency and magnitude remain highly uncertain. Projections suggest that warming will result in less snow accumulation during winter and therefore a lower risk of early spring flooding.



Source: Based on data from Dartmouth Flood Observatory (http://www.dartmouth.edu/~floods/)



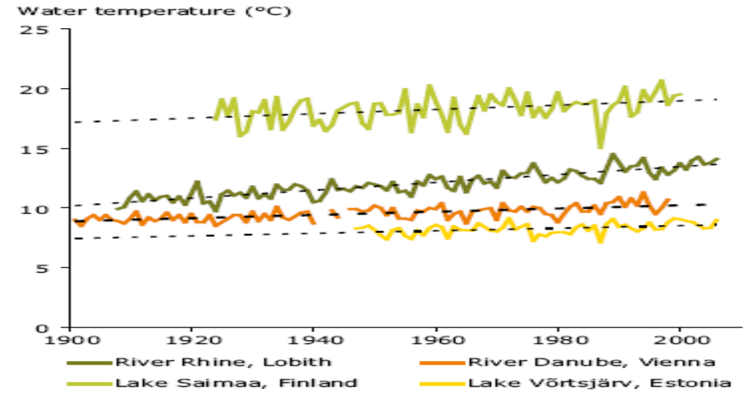
Note: Simulations with LISFLOOD driven by HIRHAM — HadAM3H/HadCM3 based on IPCC SRES scenario A2.
Source: Dankers and Feyen, 2008b.

Europe has been affected by several major droughts in recent decades, such as the catastrophic drought associated with the summer 2003 heat wave in central parts of the continent and the 2005 drought in the Iberian Peninsula, reducing overall EU cereal yields by an estimated 10 %. The drought also triggered forest fires, killing 15 people and destroying 180 000 ha of forest and farmland in Portugal alone (UNEP, 2006). Despite the absence of an overall trend in Europe as a whole, climate change has probably increased the frequency and/or severity of droughts in some regions. Climate change is projected to increase the frequency and intensity of droughts in many regions of Europe as a result of higher temperatures, decreased summer precipitation, and more and longer dry spells. The region's most prone to an increase in drought hazard are southern and south-eastern Europe, but minimum river flows will also decrease significantly in many other parts of the continent, especially in summer.

2.4.3. Water Temperature

During the last century the water temperature of some European rivers and lakes increased by 1–3 °C, mainly as a result of air temperature increase, but also locally due to increased inputs of heated cooling water from power plants. In line with the projected increases in air temperature, lake surface water temperatures may be around 2 °C higher by 2070.

Figure 5.27 **Water temperatures in four selected European rivers and lakes in the 20th century**



Note: Annual average water temperature in River Rhine (1909–2006), River Danube (1901–1998), Lake Võrtsjärv (1947–2006), and average water temperature in August in Lake Saimaa, Finland (1924–2000).

Source: River Rhine: Rijkswaterstaat; River Danube: Hohensinner *et al.*, 2006; Lake Saimaa: Korhonen (pers. com.), and Lake Võrtsjärv: Estonian Meteorological and Hydrological Institute.

Higher water temperatures, particularly in standing waters and low-flow situations in rivers, will bring about changes in the physic-chemical condition of water bodies with subsequent impacts on biological conditions.

2.4.4. Groundwater

The main pressures on the groundwater system due to climate change are sea-level rise, shrinking land ice and permafrost areas, declining groundwater recharge, especially in southern European countries, more extreme peak flows and more prolonged low flows of rivers, and increased groundwater abstraction. Regions with higher precipitation may experience rising groundwater levels that may affect houses and infrastructures. The resulting effects on groundwater quantity are shrinking of fresh groundwater resources, especially in coastal areas and in southern European countries, while brackish and salt groundwater bodies will expand. In addition, the fresh groundwater bodies will become more vulnerable to pollution through reduced turnover times and accelerated groundwater flow. Saline intrusion in coastal aquifers, making the water unsuitable for drinking, may be exacerbated by future sea-level rise. Other effects on groundwater quality are more difficult to predict as they depend strongly on changes in land-use. Nevertheless, it is already clear that groundwater temperature has increased on average by 1 °C since the 1970s (Stuyfzand *et al.*, 2007). Further increases will raise the salinity of groundwater due to increased evapotranspiration losses, increased soil CO2 pressures and increased water — rock interaction.

2.5. Impacts of Climate Change to Cyprus' Water Resources

2.5.1. Cyprus Water Bodies (in general)

Rivers

Most rivers originate in the Troodos area. 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.

Lakes

As a result of the dry Mediterranean climate, there are only 5 natural lakes which are brackish or salt. The other water bodies are created by human as a result of damming of a river or the creation of storage basins. All the lakes in Cyprus can be characterized as dynamic systems. The natural salt and brackish lakes dry up regularly, but not every year. Both the salt and brackish lakes contain typical species for these conditions. The amount of water in the reservoirs and storage basins is depending on the rainfall and use. The reservoirs are also mainly filled by the inflow of water from rivers. During winter they fill up but in summer most of the water is used and the water level declines. Consequently, the water level and size of these lakes is variable. As all reservoirs and storage basins are structured with the objective to provide water for drinking or irrigation, all these lakes have the possibility to dry out, which the often do in reality.

Groundwater bodies

Most of the Island aquifers are phreatic, developed in river or coastal alluvial deposits. These are the biggest and the most dynamic aquifers, replenished mainly by river flows and rainfall. There are three large coastal aquifers that include all the perpendicular riverbeds. The coastal parts of these aquifers are composed by sands, silts, limestones, conglomerates and clays. Riverbeds consist of alluvial deposits, gravels, sands and silts. These aquifers are phreatic and are around 30 m deep. Apart from the large but not so productive aquifer of the Troodos igneous rocks, other aquifers exist in gypsum, sandstones, limestones and chalks. These aquifers are mainly phreatic with some parts being semi-confined to confined. These parts are covered by silty-clayey layers or marls, sandy marls. It is noted that the aquifer of Troodos Mountain has been developed generally in low permeability ophiolites and locally in medium permeability fractured zones of igneous rocks and it is therefore confined in places. All the aquifers of Cyprus (66) have been grouped into 20 groundwater bodies, mainly based on lithology, the hydraulic characteristics, the pressures and the importance of each aquifer.

Ten groundwater bodies have a connection with the sea. The Lemesos groundwater body has outflow to the sea have a discharge up to 350 m3/h, while the others have discharge recharge below 150 m3/h. Most groundwater bodies are phreatic with parts that semi-confined or confined. Only the Maroni gypsum is completely confined. The ecosystem of the Fasouri marshes (near Akrotiri salt lake) is the only ecosystem in Cyprus directly depending on groundwater and more in particular on the Akrotiri groundwater body.

2.5.2. The Climate of Cyprus

General

Cyprus has an intense Mediterranean climate with the typical seasonal rhythm strongly marked in respect of temperature, rainfall and weather generally. Hot dry summers from mid-May to mid-September and rainy, rather changeable, winters from November to mid-March are separated by short autumn and spring seasons of rapid change in weather conditions. The central Troodos massif, rising to 1951 meters and, to a less extent, the long narrow Kyrenia mountain range, with peaks of about 1,000 meters, plays an important part in the meteorology of Cyprus. The predominantly clear skies and high sunshine amounts give large seasonal and daily differences between temperatures of the sea and the interior of the island which also cause considerable local effects especially near the coasts. At latitude 35^0 North, Longitude 33^0 East, Cyprus has a change in day-length from 9.8 hours in December to 14.5 hours in June. In summer the island is mainly under the influence of a shallow trough of low pressure extending from the great continental depression centered over southwest Asia. It is a season of high temperatures with almost cloudless skies. Rainfall is almost negligible but isolated thunderstorms sometimes occur, which give rainfall amounting to less than 5% of the total in the average year. In winter Cyprus is near the track of fairly frequent small depressions which cross the Mediterranean Sea from west to east between the continental anticyclone of Eurasia and the generally low pressure belt of North Africa. These depressions give periods of disturbed weather usually lasting from one to three days and produce most of the annual precipitation, the average fall from December to February being about 60% of the annual total.

Rainfall

The average annual total precipitation increases up the southwestern windward slopes from 450 millimeters to nearly 1,100 millimeters at the top of the central massif. On the leeward slopes amounts decrease steadily northwards and eastwards to between 300 and 350 millimeters in the central plain and the flat southeastern parts of the island. The narrow ridge of the Kyrenia range, stretching 100 miles from west to east along the extreme north of the island, produces a relatively small increase of rainfall to nearly 550 millimeters along its ridge at about 1,000 meters. Rainfall in the warmer months contributes little or nothing to water resources and agriculture. The small amounts which fall are rapidly absorbed by the very dry soil and soon evaporated in high temperatures and low humidity. Autumn and winter rainfall, on which agriculture and water supply generally depend, is somewhat variable. The average rainfall for the year as a whole is about 480 millimeters but it was as low as 182 millimeters in 1972/73 and as high as 759 millimeters in 1968/69 (The average rainfall refers to the island as a whole and covers the period 1951-1980). Statistical analysis of rainfall in Cyprus reveals a decreasing trend of rainfall amounts in the last 30 year. Snow occurs rarely in the lowlands and on the Kyrenia range but falls frequently every winter on ground above 1,000 metres usually occurring by the first week in December and ending by the middle of April. Altough snow cover is not continuous during the coldest months it may lie to considerable depths for several weeks especially on the northern slopes of high Troodos.

Air Temperature

Cyprus has a hot summer and mild winter but this generalization must be modified by consideration of altitude, which lowers temperatures by about 5 C per 1,000 meters and of marine influences which give cooler summers and warmer winters near most of the coastline and especially on the west coast. The seasonal difference between mid-summer and mid-winter temperatures is quite large at 18 C inland and about 14 C on the coasts. Differences between day maximum and night minimum temperatures are also quite large especially inland in summer. These differences are in winter 8 to 10 C on the lowlands and 5 to 6 C on the mountains increasing in summer to 16 C on the central plain and 9 to 12 C elsewhere. In July and August the mean daily temperature ranges between 29 C on the central plain and 22 C on the Troodos mountains, while the average maximum temperature for these months ranges between 36 C and 27 C respectively. In January the mean daily temperature is 10 C on the central plain and 3 C on the higher parts of Troodos mountains with an average minimum temperature of 5 C and 0 C respectively. Frosts are rarely severe but are frequent in winter and spring inland and in some years handicap the economically important production of early vegetable crops and main citrus crops.

2.5.3. Trends in Precipitation and Temperature in Cyprus during the 20th Century

During the 20th century remarkable variations and trends were observed in the climate of Cyprus, particularly in the two basic climatic parameters, precipitation and temperature. Similar climatic variations and trends were observed in countries of the eastern Mediterranean and the Middle East, which is an evidence of change in the general circulation of the atmosphere in the area. In Cyprus the precipitation presented a decreasing trend and the temperature presented an increasing trend. The rates of change of precipitation and temperature are greater during the second half of the century compared to those in the first half of the century. In the last decades the number of years of low precipitation and drought is greater than before and the semi – arid conditions both in Cyprus and in the eastern Mediterranean were deteriorated. Also, the most of the warm years in the century were observed in the last 20 years. The decrease in the amount of precipitation was remarkable. While the average annual precipitation in the first 30-year period of the century was 559 mm, the average precipitation in the last 30-year period was 462 mm, which corresponds to a decrease of 17%. On the other hand, the average annual temperature in Cyprus, both in urban and in rural areas, presented an increasing trend. The greater increase in temperature in the towns is due to the urbanization effect, however, the fact that an increase is also observed in rural areas, it is indicative of the general increase in temperature in our area as well as globally. In Nicosia the average annual temperature increased from 18.9°C in the first 30-year period of the century to 19.7°C in the last 30-year period, an increase of 0.8°C.

Precipitation

The rate of decrease of the average precipitation in Cyprus during the 20th century 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. This is shown in Table 1, where the hydro-meteorological years as from 1901-02 are classified according to the normal precipitation of the period 1961-1990.

TABLE 1

AVERAGE ANNUAL PRECIPITATION IN THE AREA UNDER GOVERNMENT CONTROL CLASSIFICATION OF THE YEARS ACCORDING TO NORMAL (1961-1990)

S/N	**Severe Drought**	**Drought**	**Low Precipitation**	**About Normal**	**About Normal**	**High Precipitation**	**Very high Precipitation**	**Extr. High Precipitation**
	≤ 70%	**71-80%**	**81-90%**	**91-100%**	**101-110%**	**111-120%**	**121-130%**	**>130%**
1	1901-02	1916-17	1915-16	1902-03	1903-04	1909-10	1913-14	1904-05
2	1931-32	1933-34	1927-28	1907-08	1905-06	1918-19	1922-23	1906-07
3	1932-33	1940-41	1956-57	1908-09	1910-11	1920-21	1928-29	1911-12
4	1963-64	1950-51	1959-60	1917-18	1912-13	1936-37	1930-31	1919-20
5	1972-73	1958-59	1971-72	1924-25	1914-15	1937-38	1938-39	1925-26
6	1990-91	1969-70	1978-79	1960-61	1921-22	1941-42	1942-43	1929-30
7		1973-74	1981-82	1967-68	1923-24	1947-48	1944-45	1934-35
8		1989-90	1982-83	1970-71	1926-27	1949-50	1951-52	1952-53
9		1995-96	1983-84	1976-77	1935-36	1975-76	1961-62	1966-67
10		1996-97	1985-86	1977-78	1939-40	1979-80	1962-63	1968-69
11		1997-98	1993-94	1984-85	1943-44	1980-81	1974-75	
12		1999-00		1988-89	1945-46		1987-88	
13				1994-95	1946-47		1991-92	
14				1998-99	1948-49			
15				2000-01	1953-54			
16					1954-55			
17					1955-56			
18					1957-58			
19					1964-65			
20					1965-66			
21					1986-87			
22					1992-93			

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.

TABLE 2
ANNUAL PRECIPITATION IN THE LAST DECADE

Hydrometeorological Year	**Annual Precipitation (mm)**	**% Normal (1961 – 1990) (%)**
1991-1992	637	127
1992-1993	509	101
1993-1994	417	83
1994-1995	493	98
1995-1996	383	76
1996-1997	399	79
1997-1998	388	77
1998-1999	473	94
1999-2000	363	72
2000-2001	468	93
Average for the Decade	**453**	**90**

Temperature

Temperature in Cyprus during the 20th century followed a reverse trend than the precipitation, with a rate of increase of 0.01°C per year. In the period 1976-1998 the average rate of increase in temperature was 0.035°C / year in the towns and 0.015°C in the rural areas. The urbanization effect plays an important role in the temperature increase in towns however, the increase in the temperature in rural areas is indicative of the climate change in our area in the last decades. In Cyprus, as well as globally, most of the warm years in the 20th century occurred in the last two decades. The year 1998 was the warmest in Cyprus and globally. In Cyprus during August 1998 we experienced a very severe heat wave.

2.5.4. Climatic changes – Conditions after 1990

Climatic changes have affected Cyprus. The changes are obvious in Precipitation and Temperature. The average annual Precipitation in the period 1991/ 92 - 2007/ 08 (17 hydrometeorogical years) is 457 mm or 9% lower than normal (503 mm, period 1961-1990). The average annual Temperature in the period 1991-2007 is 17,7^{0}C or 0,5^{0}C higher than normal (17,2^{0}C, period 1961-1990). According to the above rate of changes it is expected that by 2030 Precipitation will decrease by 10 - 15% and Temperature will increase by 1,0 - 1,5^{0}C compared to the normal values of the period 1961- 1990. Since the last couple of decades, all of Cyprus's water resources were originating from rainfall. Based on a long series of observations, the mean annual rainfall including snowfall it was 503 mm, but observations on the last 4 decades indicate that it is reduced to 463 mm. The amount of water corresponding to the unoccupied part of Cyprus is equivalent to 2.670 million cubic meters but only the 14% or the equivalent of 370 mcm is available for utilization since the remainder 86% returns to the atmosphere as direct evaporation. The rainfall is not uniformly distributed where most of it falls on the two mountainous areas whereas the eastern low level and coastal areas take a very small amount of rain. It must be noted also, that Cyprus is experiencing a big variation of rainfall for year to year, and also from frequent droughts which have duration of two to three years. The mean annual amount of water of 370 mcm is distributed roughly with the ratio of 1.75:1 between surface and groundwater respectively.

Impacts on Water Resources

Since Cyprus' water resources are totally precipitation-dependent, they are directly affected by climate changes. Droughts are the major problem of Cyprus, regarding climate change. Since 1970 a 15% decline of precipitation has been observed, with a corresponding 40% reduction of river flow. This trend is possible to continue in the following years. The mean annual quantity of fresh water in Cyprus is 370millions m3 and is distributed as 462m3 per person. This classifies Cyprus among countries with increased water resources depression and that is why many investments have been made, including improved irrigation systems, as well as dams of total capacity of 327millions m3. Dams helped the homogenous distribution of water regardless the precipitation distribution and they reduced to a degree, the problems of short lasting droughts. However, those dams could not balance the continuous impacts of climate change; therefore, the Cyprus Government had to invest on alternative sources of water, like the construction of 3 desalination plants (Location: Larnaca, Dekelia and Episkopi) which produces more than 30millions m3/year of potable water. 69% of all annual water needs goes to agriculture/irrigation, 25% goes to water supplies and 6% covers the needs of industry (1%) and tourism (5%). Moreover, there is a 2-3 % increase of the demands for drinkable water every year. Regarding the groundwater, the annual abstraction comes up to 140 million m3, where 30 out of 140millions.m3 are excess. That results in exhaustion of groundwater and in saline intrusion in coastal aquifers. Furthermore, aquifers are becoming more and more polluted by fertilizer usage (nitric salts) in agriculture, and by the industry and residential development in a lesser degree. In addition the quality of groundwater in Cyprus is affected by natural causes like geological formations which release sulfate and chloride salts of sodium and boron. The high degree of evaporation and low degree of precipitation in Cyprus contribute to the increased salinity of groundwater. As a conclusion we can say that 20% of the rivers, 16% of the coastal water and 74% of the groundwater are in danger of not reaching the goal standards of good quality water by 2015.

3. Climate Change and Agriculture

Climate is an important driving force in the distribution and functioning of natural systems (Parmesan and Yohe, 2003). The biodiversity, species, habitats and ecosystems as well as agricultural crops have changed continuously during ancient and recent times due to climate conditions. Some species have become extinct and some have become dominant in different areas of the planet depending on the specific climate characteristics of an area.

According to the IPCC report (2007), climate change patterns will cause several changes to agricultural practices around the world, identified as the following:

- in mid to high latitude regions, moderate warming benefits cereal crop and pasture yields, but even slight warming decreases yields in seasonally dry and tropical regions.
- Climate changes increases the number of people at risk of hunger marginally, with respect to overall large reductions due to socio-economic development.
- Projected changes in the frequency and severity of extreme climate events have significant consequences on food and forestry production, and food insecurity, in addition to impacts of projected mean climate.
- Smallholder and subsistence farmers, pastoralists and astisanal fisher folk are likely to suffer complex, localized impacts of climate change.
- Globally, forestry production is estimated to change only modestly with climate change in the short and medium term.
- Locally, extinction of particular fish species is expected.
- Food and forestry trade is projected to increase in response to climate change, with increased food-import dependence of most developing countries.

Specific risks faced by agriculture (EU European Commission Directorate-General for Agriculture and Rural Development, 2008):

a. Water shortages

Most of the impacts of climate change on agriculture will come through water. Climate change is likely to result in a decrease in annual water availability in many parts of the world because of an expected reduction in summer precipitation − especially in the southern hemisphere. In western and Atlantic areas, summers are likely to be dryer and hotter and reduced water resources during this season may lead to conflicting demands between agriculture and other users. The increased risk of water shortages will have a major impact on agricultural production.

b. Weather hazards

Impacts from increasing frequency of extreme weather events such as hail, intense winter precipitation, heat waves and droughts will be felt everywhere in the world. A succession of floods, droughts and storms in recent years has shown agriculture's vulnerability to extreme conditions, and according to the IPCC report, their frequency could increase in the short to medium term up to 2020. In particular, the risk of drought in the southern hemisphere and the possibility of floods in central and northern world are expected to rise.

c. Increased pest problems

Adverse impacts can also be expected from the likely rise in the spatial distribution and intensity of existing pests, diseases, and weeds, due to higher temperatures and humidity. The magnitude of the overall effect will probably be regionalized, depending on the specific conditions of the area. Farmers will need to face increased pest problems.

d. Impact on crop yields and crop distribution

Climate changes will affect the level and variability of crop yields, livestock management, and the location of production as agro-climatic zones which are likely to shift to more northern latitudes. These impacts may even put domestic food supply at risk in certain parts of the world and can also lead to increased price instability which will mean greater risks for farmers' incomes.

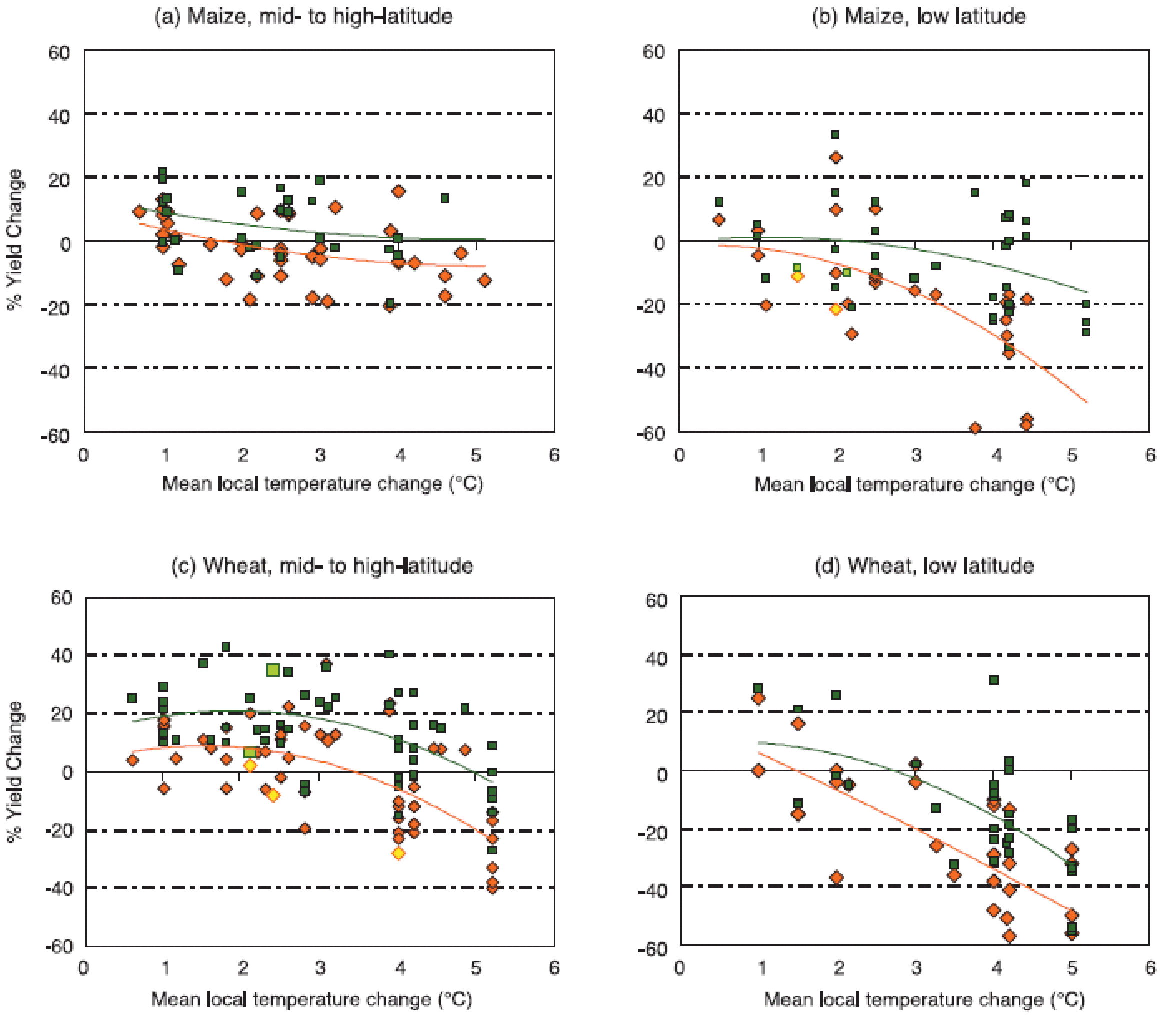
e. Impacts on consumers

The probability of reduced production in some regions, variability of output, alterations in seasonal patterns, possibly increased farmer costs etc, as a result of climate change, will have knock-on effects for consumers. This may come in the form of supply dislocation and/or price variation. In some countries, however, depending on their specific circumstances, the yields and the range of farm produce could improve as the climate changes.

f. Climate effects in forests

The forest areas will also be widely affected by changing climatic conditions. Warming is likely to intensify the risk of forests fires and pests; in the longer term it will also affect tree species composition and timber production capacity, although the incidence of these impacts will be geographically different. Extreme weather events, such as heavy winds, storms, and prolonged heat waves and droughts will also have significant impacts on forests. In the long term, climate change might jeopardize the capacity of our forests to provide economic, social and ecological services.

According to following figure which was included in the IPCC Assessment for 2007 (Working Group II), there is a sensitivity of cereal yield to climate change for maize and wheat. The responses include cases without adaptation (orange dots) and with adaptation (green dots). The studies on which this figure is based span a range of precipitation changes and CO2 concentrations, and vary in how they represent future changes in climate variability. For instance, lighter-colored dots in (b) and (c) represent responses of rain-fed crops under climate scenarios with decreased precipitation.



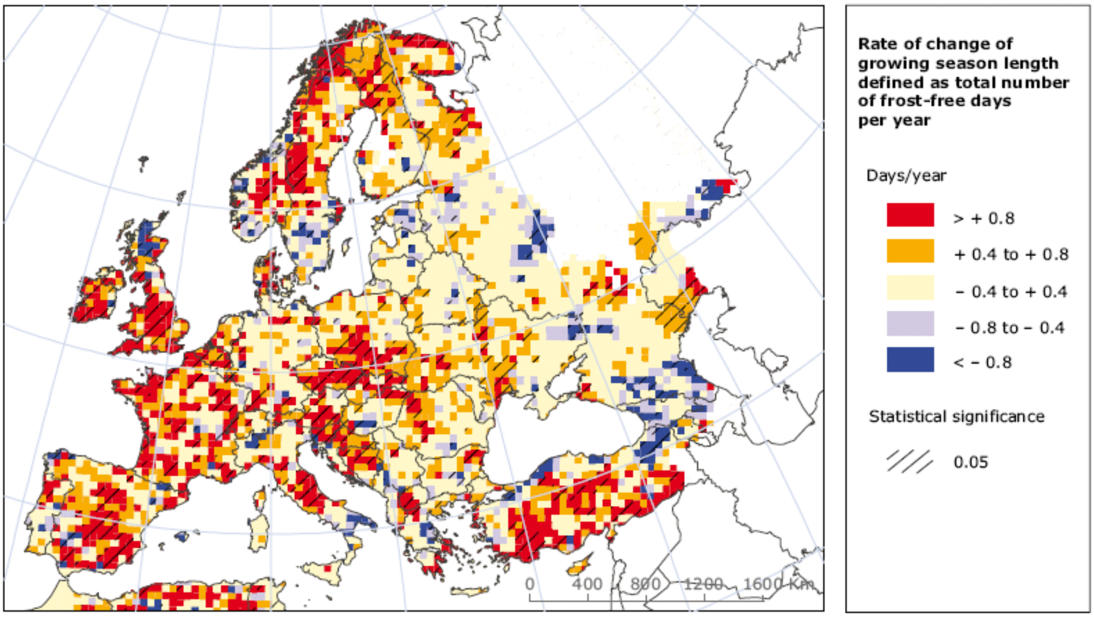
3.1 Climate change and agriculture in Europe

According to the EEA’s assessment on the Impacts of Europe's changing climate — a 2008 indicator-based assessment, Europe will witness potential positive impacts of climate change on agriculture in general which are related to longer growing seasons and new cropping opportunities in northern Europe, and increased photosynthesis and CO2 fertilization throughout Europe. These possible benefits are counterbalanced by potentially negative impacts that include increased water demand and periods of water deficit, increased pesticide requirements and crop damage, and fewer cropping opportunities in some regions in southern Europe (Menzel *et al.*, 2003).

The changes in atmospheric CO2 levels and increases in temperature are changing the quality and composition of crops and grasslands and also the range of native/alien pests and diseases. These may affect livestock and ultimately humans as well as crops. In addition, the increase in ozone concentrations related to climate change (Meleux *et al.*, 2007) is projected to have significant negative impacts on agriculture, mainly in northern mid-latitudes (Reilly *et al.*, 2007).

The key messages from the EEA report regarding climate change and agriculture in Europe focuses on the following:

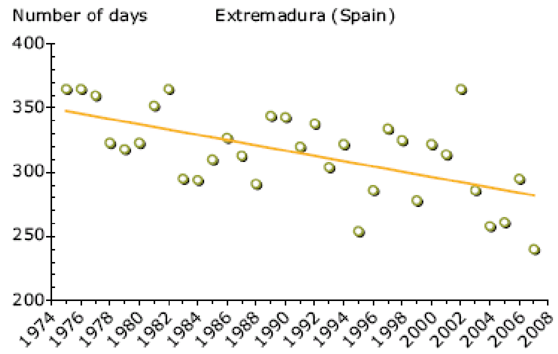
- Evidence suggests that the length of the growing season of many agricultural crops in Europe has changed.
- A longer growing season increases crop yields and insect populations and favors the introduction of new species in areas that were not previously suitable for these species.
- Locally at southern latitudes, the trend is towards a shortening of the growing season, with consequent higher risk of frost damage from delayed spring frosts.

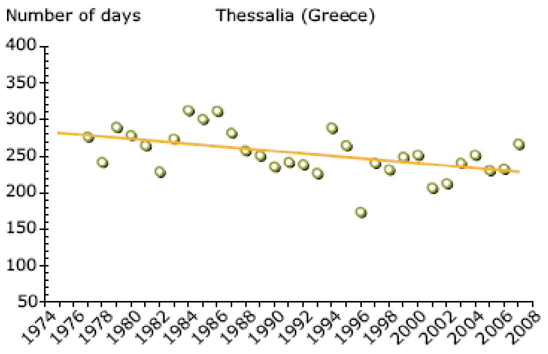


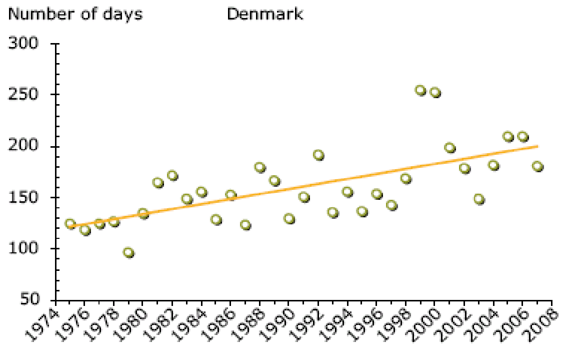
The above map shows the rate of change of crop growing season length (defined as total number of frost-free days per year) for the period 1975–2007. (Source: MARS/STAT database (Genovese, 2004a, 2004b)).

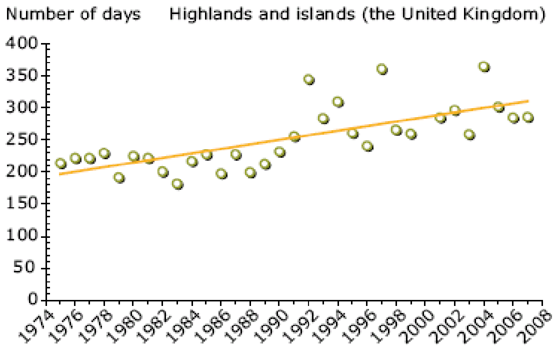
The observed trends are in line with projections for temperature increase, a further lengthening of the growing season as well as a northward shift of species. The length of the growing season will be influenced mainly by the increase in temperatures in autumn and spring. According to the IPCC analysis, Europe will warm in all seasons for all scenarios, but warming will be greater in western and southern Europe in summer and northern and eastern Europe in winter. More lengthening of the growing season is therefore expected in these northern and eastern areas, while in western and southern Europe the limited water availability and high temperatures stress during summer will hinder plant growth.

The same source (MARS/STAT database (Genovese, 2004a, 2004b)) identified the increase in the number of frost-free days since 1975 in selected European areas as follows:

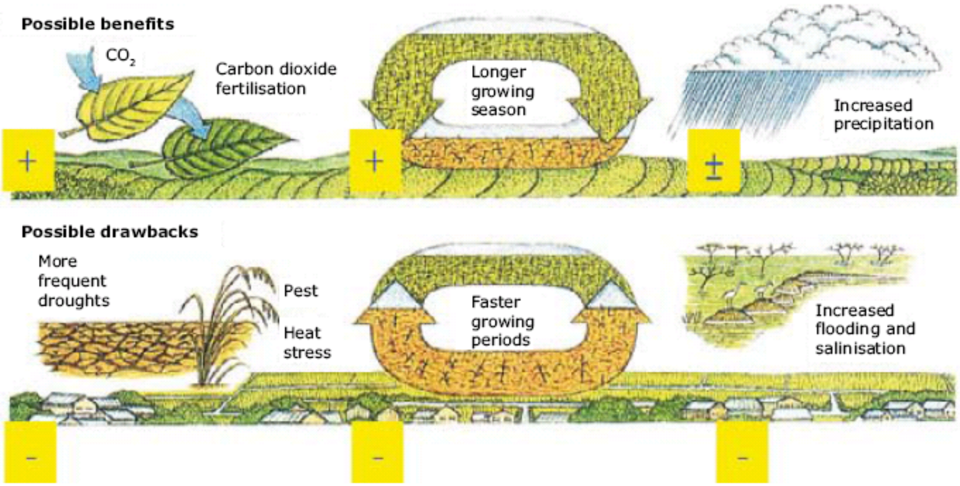








Changes in crop phenology provide important evidence of responses to recent regional climate change (IPCC, 2007). Although phenological changes are often influenced by management practices and new farming technologies, recent warming in Europe has clearly advanced a significant part of the agricultural calendar. Specific stages of growth (e.g. flowering, grain filling) are particularly sensitive to weather conditions and critical for final yield. The timing of the crop cycle (agrophenology) determines the productive success of the crop. In general, a longer crop cycle is strongly correlated with higher yields, since a longer cycle permits maximum use of the available thermal energy, solar radiation and water resources. The impacts of unfavorable meteorological conditions and extreme events vary considerably, depending on the timing of occurrence and the development stage of the crops. However, shortening of the growth period can also help avoid summer stress conditions in areas prone to drought.



According to Bongaarts(1994) and the reference figure above, a changing climate will affect agro-ecosystems in various ways, with either benefits or negative consequences dominating in different agricultural regions. Rising atmospheric CO2 concentration, higher temperatures, changing patterns of precipitation, and changing frequencies of extreme events will have significant effects on crop production, with associated consequences for water resources and pest/disease distributions.

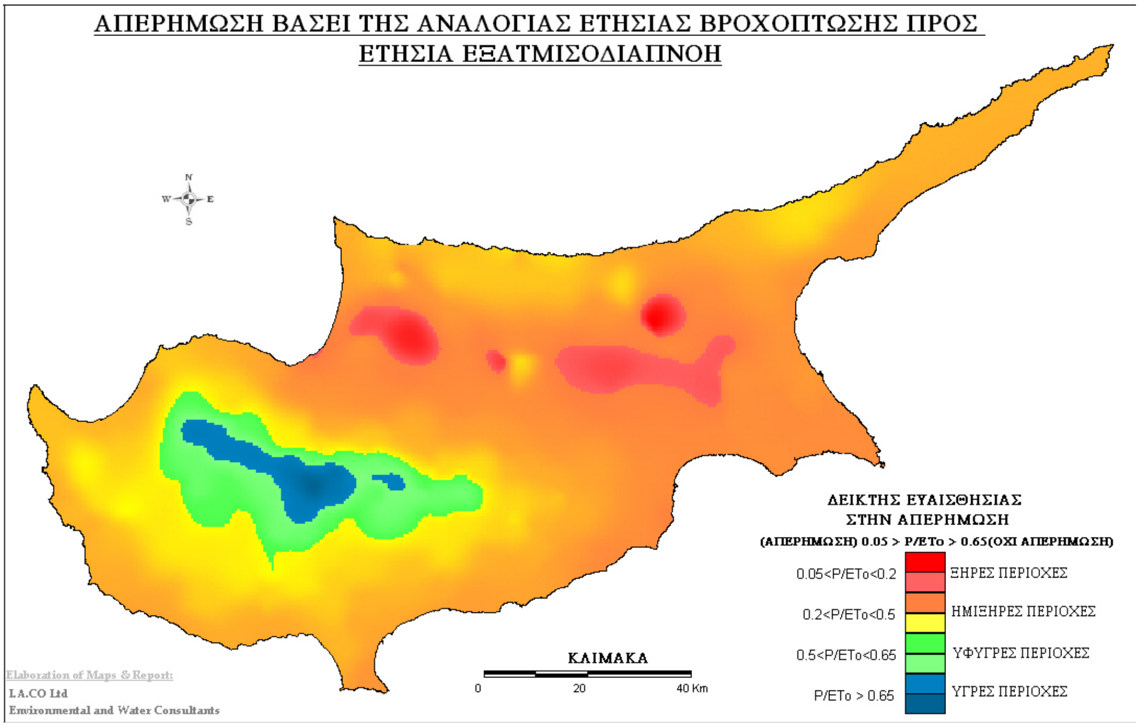
According to the EEA report, climate change introduces new uncertainties for the future of the agricultural sector. Climatic conditions are projected to become more erratic with an increase in the frequency of extreme events (floods, hurricanes, heat waves, severe droughts. Biomass production of plants, and thus crop yields, are fundamentally determined by climatic conditions, i.e. the stable availability of energy (radiation, temperature) and water (rain) to support growth. Other environmental and anthropogenic factors, such as soil fertility, crop varieties and farming practices, also influence crop yields. These factors imply that, in principle, many adaptation options are available to adjust agricultural practices to the changing climate, but that opportunities differ between regions.

The report also states that climate change may affect agriculture primarily through increasing atmospheric CO2, rising temperatures and changing rainfall. Where rainfall does not limit crop growth, these conditions allow for earlier sowing dates and enhanced crop growth and yield. Where reduced rainfall is predicted, however, the increased requirement for irrigation water can have an overall negative impact in economic and environmental terms. In these areas, increased water shortages are expected to increase competition for water between sectors (tourism, agriculture, energy, etc.), particularly in southern Europe and the Mediterranean, where the agricultural demand for water is greatest.

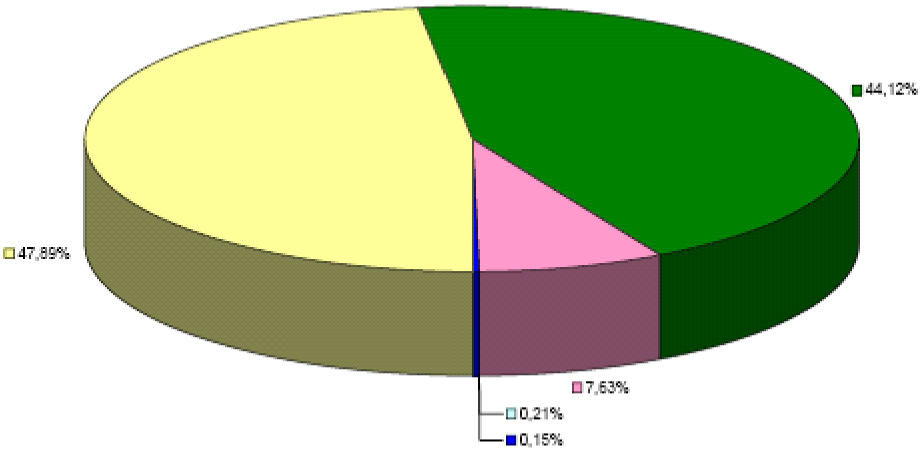
No quantitative projections of irrigation demand are available. Many climatic projections for Europe (IPCC, 2007) foresee a very likely precipitation increase in the north and a decrease in the south, especially during the summer. Also the extremes of daily precipitation are projected to increase in the north and the annual number of rainy days to decrease in the Mediterranean. The risk of summer drought is therefore likely to increase in central Europe and in the Mediterranean area. Agricultural crops will be affected, among other factors, in positive and negative ways by changes in the length and timing of the vegetative cycle. Crop management will have to be adapted in order to try to avoid crucial development stages sensitive to water-stress (flowering, grain filling, etc.) occurring during generally dry periods.

3.2. Climate change and agriculture in Cyprus

Cyprus is one of the countries experiencing the major impacts of climate change that have been referred to above, due to its location in the eastern Mediterranean region, with a decrease in rainfall, increase in temperature with all the related consequences in agricultural practices. According to a recent report by the Ministry of Agriculture, Natural Resources and Environment on desertification, the following map shows areas in Cyprus prone to desertification (in red and orange), which indicates the largest area of the island being in risk of desertification.



Accordingly, the same report indicates land use in the island as follows:



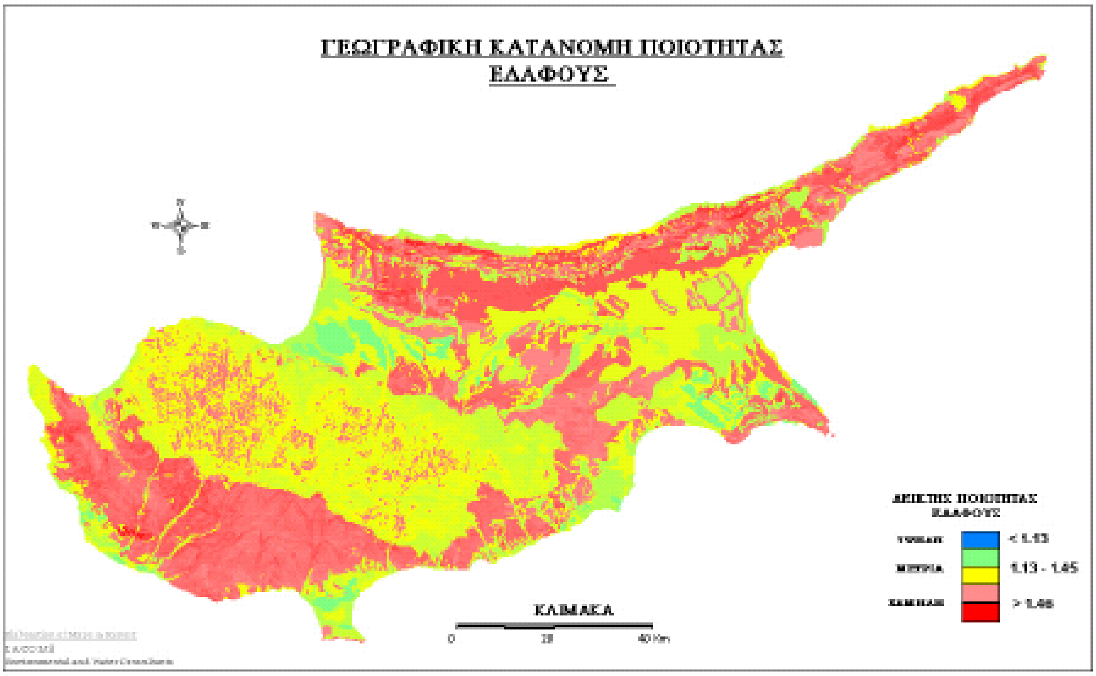
According to the study, agriculture covers 47.59% of current land use (443.043 hectares), with forests covering 407.858 hectares and 44,12% of the island, and other land uses cover much smaller areas. Specifically, artificial land cover are about 70.233 hectares (7,63%), wetlands are about 1955 hectares (0,21%) and technical water bodies cover 1401 hectares (0,15 %).

Changes in climate changes have resulted in changes in land use and a shift in the agricultural practices of the island. Although the largest area of Cyprus is considered to be agricultural land, there is a general trend of decrease in agricultural practices and population in the rural areas. The interest of the working population towards agriculture has decreased considerably, leading the areas in conditions of abandonment, desertification, and reduction of natural resources.

The contribution of the agricultural sector in the total economy of the island is still important, representing 3.1% of GDP, 6.5% of the working population and 21.2% of exports (Statistical Service, data for 2003).

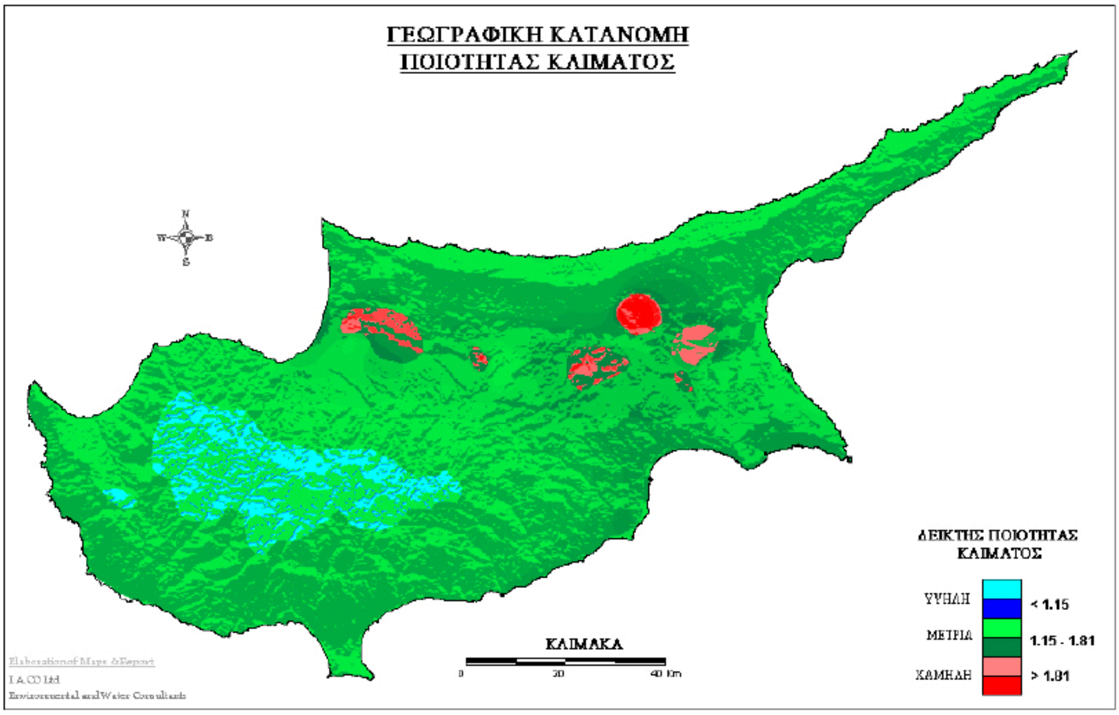
As stated, the total agricultural land use in Cyprus for 2003 was 153.300 hectares, with yearly cultivation being 69.8% and permanent crops are 26.4%. The major products are typical for the Mediterranean (potatoes, vegetables, citrus fruits, olives and grapes). The wheat sector of Cyprus is facing major problems due mainly to the difficult conditions for cultivation.

The report concludes with a series of maps indicating the major problems caused by climate changes with serious impacts on current agricultural practices as well as trends for the future.



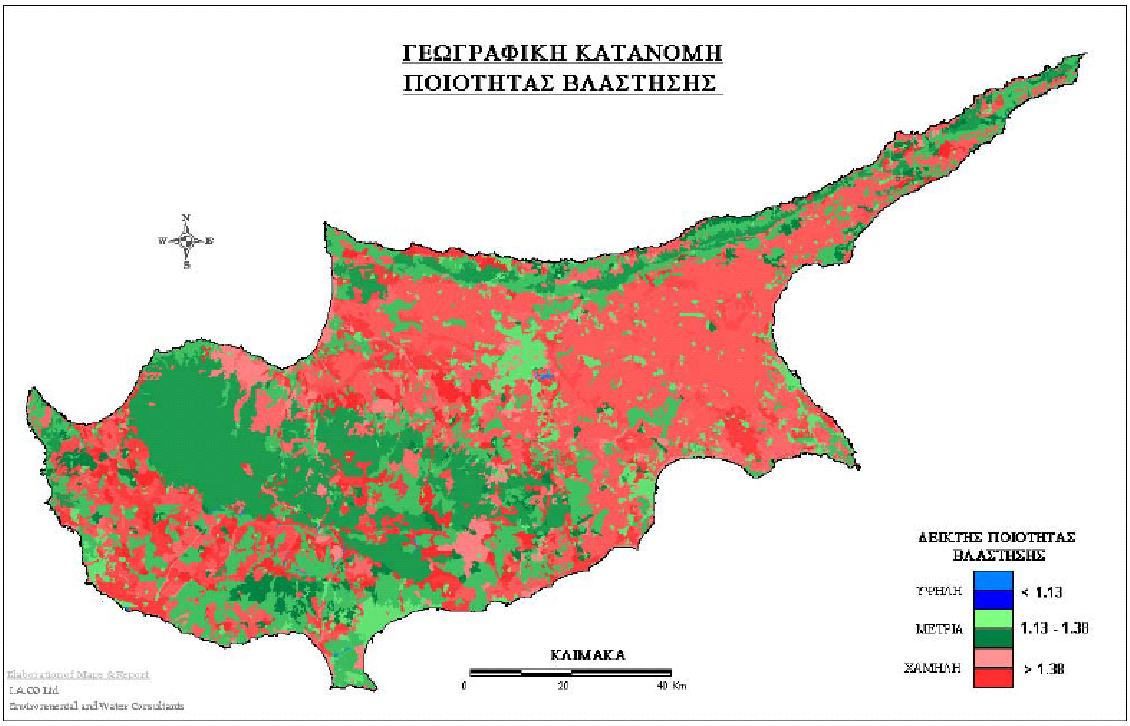
The first map indicates the geographical distribution of the quality of soil for agricultural purposes, with the indicator showing as high quality of soil less that 1.13 (green and blue color), medium (1.13-1.45) in yellow and pink color and low (>1.46) in red color.

The next map shows the geographical distribution of good climate conditions.



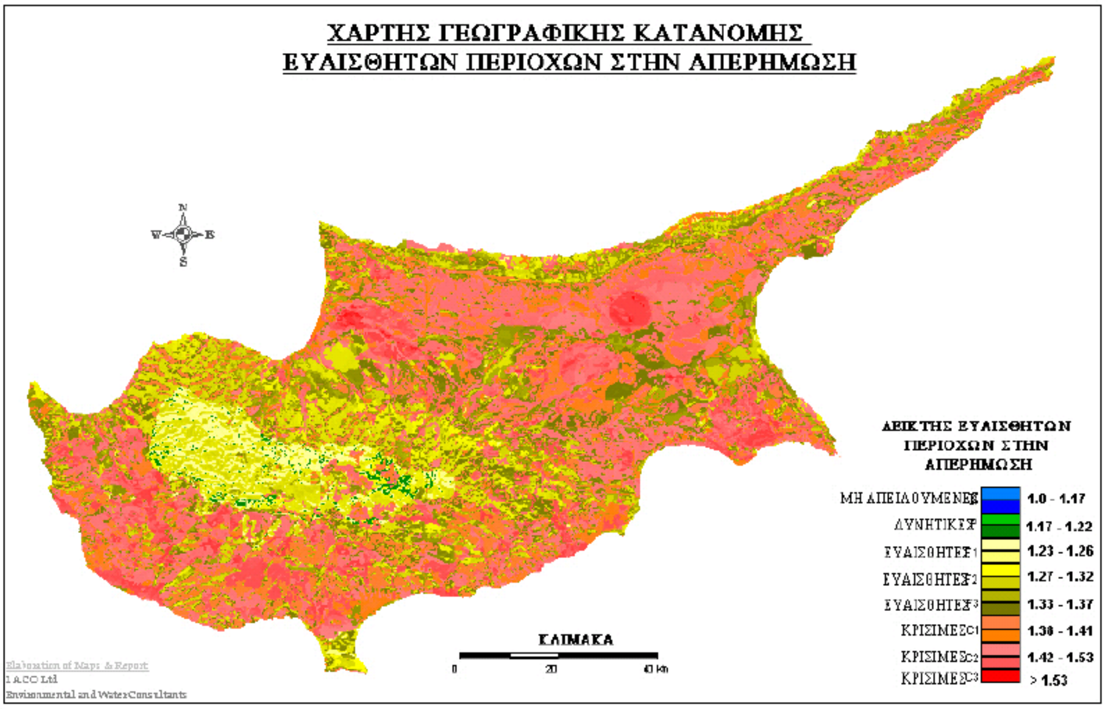
This map shows that the indicator of climate quality has high quality indicator in the blue areas, medium in the green areas and low in the pink and red areas.

Next is the map showing indicators of the quality of flora in Cyprus.



The geographical distribution shows mostly low quality of flora in the red and pink areas, indicators of medium quality in green and high quality in blue.

Last, is the map to the areas prone to desertification in Cyprus.

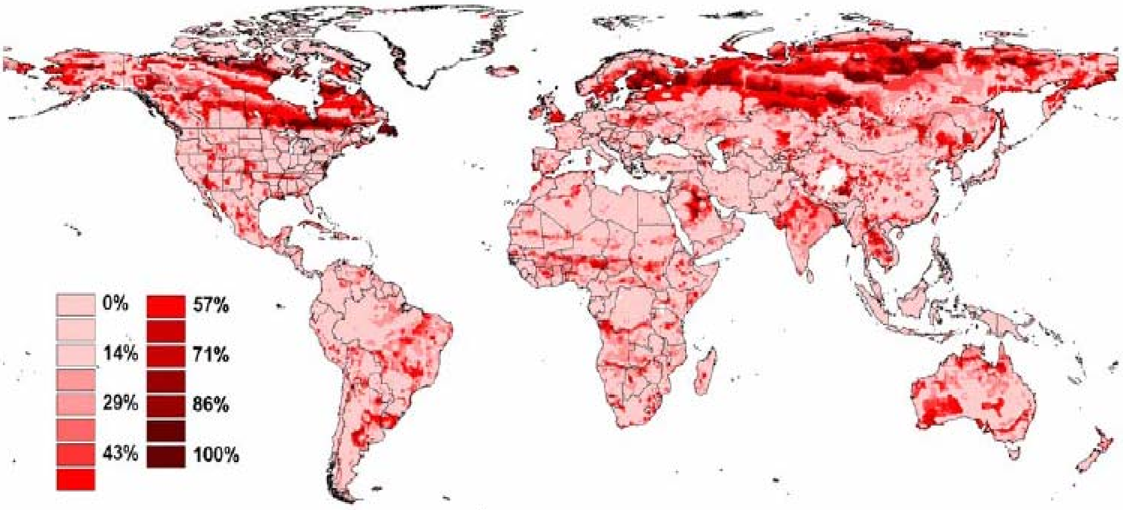


The areas with the most intense red colors indicate areas in critical conditions towards desertification, where colors of orange, yellow and white indicate areas sensitive to desertification.

4. Climate Change and Biodiversity

According to the IPCC report on Climate Change and Biodiversity, at the global level, human activities have caused and will continue to cause a loss in biodiversity through land-use and land-cover change; soil and water pollution and degradation (including desertification), and air pollution; diversion of water to intensively managed ecosystems and urban systems; habitat fragmentation; selective exploitation of species; the introduction of non-native species; and stratospheric ozone depletion. The current rate of biodiversity loss is greater than the natural background rate of extinction. It has been observed the climate change enhances the trend of biodiversity loss.

Changes in climate exert additional pressure and have already begun to affect biodiversity. The atmospheric concentrations of greenhouse gases have increased since the pre-industrial era due to human activities, primarily the combustion of fossil fuels and land-use and land-cover change. These and natural forces have contributed to changes in the Earth’s climate over the 20th century: Land and ocean surface temperatures have warmed, the spatial and temporal patterns of precipitation have changed, sea level has risen, and the frequency and intensity of extreme events have increased. These changes, particularly the warmer regional temperatures, have affected the timing of reproduction in animals and plants and/or migration of animals, the length of the growing season, species distributions and population sizes, and the frequency of pest and disease outbreaks. Some coastal, high-latitude, and high-altitude ecosystems have also been affected by changes in regional climatic factors.



The above graph is taken from a research from J.R. Malcom (University of Toronto, Canada), who run a series of models regarding global impact of climate change on biodiversity, these models showed a shift in biome in response to the 21st century's climate change, where migration needs to be at rates in excess of 1 km / year to keep pace with movement of their climate conditions.

Changes in the environment due to climate change that have impacts on ecosystem balance (IPCC report):

a. Changes in Atmospheric Concentrations of Greenhouse Gases: the atmospheric concentrations of greenhouse gases have increased due to human activities, reaching their highest recorded levels in the 1990s, and most of them continue to increase primarily due to the combustion of fossil fuels, land use, and land use change.

b. Changes in Earth's Surface Temperature: during the last 100 years we have witnessed an increased warming of land and ocean. The global mean surface temperature has increased by 0.6°C (0.4–0.8°C), with the largest increases in temperature occurring over the mid- and high latitudes of northern continents, where land areas have warmed more than the oceans, and nighttime temperatures have warmed more than daytime temperatures.

c. Changes in Precipitation: mean precipitation has very increased during the 20th century by 5 to 10% over most mid- and high latitudes of Northern Hemisphere continents, but in contrast rainfall has decreased by 3% on average over much of the subtropical land areas. The increase in global mean surface temperature leads eventually to changes in precipitation and atmospheric moisture because of changes in atmospheric circulation, a more active hydrological cycle, and increases in the water-holding capacity throughout the atmosphere. In addition, there has been a 2 to 4% increase in the frequency of heavy precipitation events in the mid- and high latitudes of the Northern Hemisphere.

d. Changes in Snow Cover, Sea and River Ice, Glaciers, and Sea Level: Snow cover and ice extent have decreased by about 10% on average in the Northern Hemisphere since the late 1960s and the annual duration of lake- and river-ice cover in the mid- and high latitudes of the Northern Hemisphere have been reduced by about 2 weeks over the 20th century. In addition, there has been a significant decrease of mountain glaciers in the Northern Hemisphere during spring and summer by about 10 to 15% from the 1950s and the Arctic sea-ice thickness has declined by about 40% during late summer and early autumn in the last 3 decades of the 20th century. A consequence of the above is the rise in sea level. Based on tide gauge records, the average annual rise in sea level was between 1 and 2 mm during the 20th century. It is very likely that the 20th century warming contributed significantly to the observed sea-level rise through thermal expansion of seawater and widespread loss of land ice.

e. Changes in Climate Variability and Extreme Weather Events: there have been observed changes in some extreme weather and climate events and there have been higher maximum temperatures, more hot days, and an increase in heat index, and higher minimum temperatures and fewer cold days and frost days over nearly all land areas. In addition, there has been an increase in summer continental drying and associated risk of drought in a few areas.

The IPCC evaluated the effect of climate change on biological systems by assessing 2,500 published studies. Of these, 44 studies, which included about 500 taxa, met the following criteria: 20 or more years of data; measuring temperature as one of the variables; the authors of the study finding a statistically significant change in both a biological/physical parameter and the measured temperature; and a statistically significant correlation between the temperature and the change in the biological/physical parameter. Some of these studies investigated different taxa (e.g., bird and insect) in the same paper. Of a total of 59 plants, 47 invertebrates, 29 amphibians and reptiles, 388 birds, and 10 mammal species, approximately 80% showed change in the biological parameter measured (e.g., start and end of breeding season, shifts in migration patterns, shifts in animal and plant distributions, and changes in body size) in the manner expected with global warming, while 20% showed change in the opposite direction. Most of these studies have been carried out (due to long-term research funding decisions) in the temperate and high latitude areas and in some high-altitude areas. These studies show that some ecosystems that are particularly sensitive to changes in regional climate (e.g., high-altitude and high-latitude ecosystems) have already been affected by changes in climate.

There has been a visible impact of regional climate change, particularly increases in temperature, on biological systems in the 20th century. In many parts of the world, the observed changes in these systems, either anthropogenic or natural, are coherent across diverse localities and are consistent in direction with the expected effects of regional changes in temperature. The probability that the observed changes in the expected direction (with no reference to magnitude) could occur by chance alone is negligible. Such systems include, for example, the timing of reproduction or migration events, the growing season length, species distributions, and population sizes. These observations implicate regional climate change as a prominent contributing causal factor. There have been observed changes in the types, intensity, and frequency of disturbances (e.g., fires, droughts, blowdowns) that are affected by regional climatic change and land-use practices, and they in turn affect the productivity of and species composition within an ecosystem, particularly at high latitudes and high altitudes. Frequency of pests and disease outbreaks has also changed especially in forested systems and can be linked to changes in climate.

Extreme climatic events and variability (e.g., floods, hail, freezing temperatures, tropical cyclones, droughts) and the consequences of some of these (e.g., landslides and wildfire) have affected ecosystems in many continents. Extreme climatic events had major impacts on many terrestrial ecosystems—both intensively and non-intensively managed (e.g., agriculture, wetlands, rangelands, forests)—affecting the human populations that rely on them.

The IPCC report has identified the major changes in biodiversity resulting from changes in climate conditions as follows:

Changes in the timing of biological events have already been observed. Such changes are for example warmer conditions during autumn-spring affect the timing of emergence, growth, and reproduction of some cold-hardy invertebrate species, there is earlier start of breeding of some bird species in Europe, North America, and Latin America, changes in insect and bird migration with earlier arrival dates of spring migrants in the United States, later autumn departure dates in Europe, and changes in migratory patterns in Africa and Australia, ,mismatch in the timing of breeding of bird species with other species, including their food species and earlier flowering and lengthening of the growing season of some plants.

Changes in morphology, physiology, and behavior of some species associated with changes in climatic variables, for example, earlier sexual maturity and faster growing in warmer springs leading to increases in adult body size.

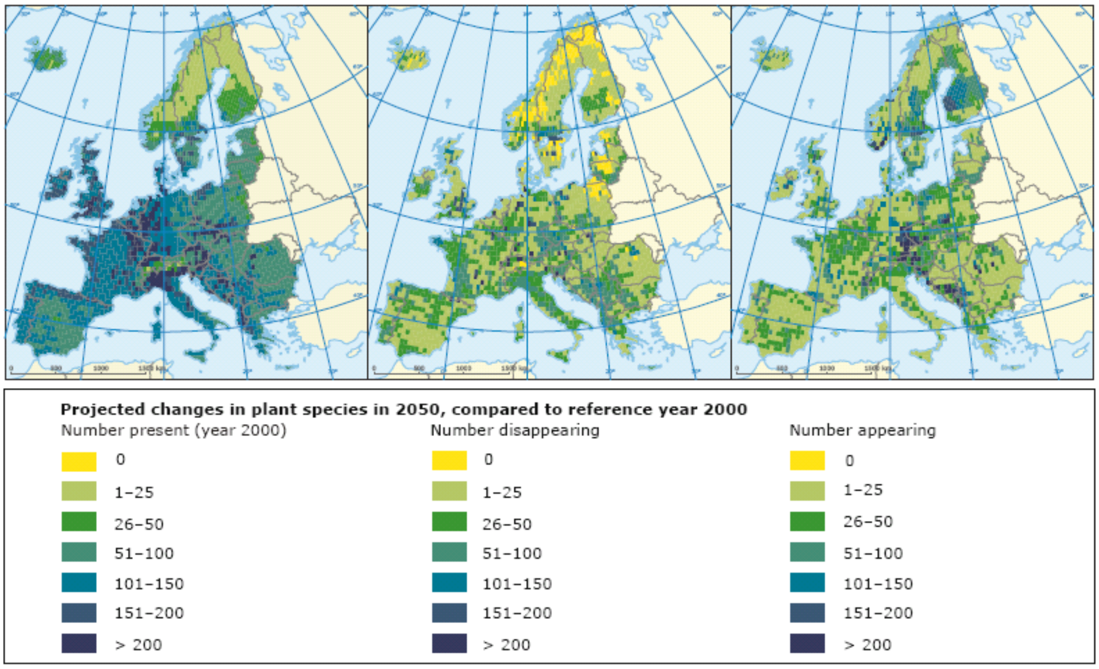
Changes in species distribution linked to changes in climatic conditions, leading to shifts in animal ranges and densities, for example: ranges of butterflies in Europe and North America have been found to shift pole ward and up in elevation as temperatures have increased, population increases of several species of forest butterflies and moths in central Europe in the early 1990s have been linked to increased temperatures, the ranges of some birds have moved also pole ward in Antarctica.

Changes in climatic variables have led to increased frequency and intensity of outbreaks of pests and diseases. For example, spruce budworm outbreaks frequently follow droughts and/or dry summers in parts of their range, the distribution of vector-borne diseases (e.g., malaria and dengue) and food- and water-borne (e.g., diarrhea) infectious diseases, thus the risk of human diseases, have been affected by changes in climatic factors.

Changes in stream flow, floods, droughts, water temperature, and water quality have affected biodiversity, in cases where regional climate change impacts on elements of the hydrological cycle with warmer temperatures, leading to intensification of the hydrological cycle. Lakes and reservoirs specifically in semi-arid parts of the world respond to climate variability by pronounced changes in storage, leading to complete drying up. Changes in rainfall frequency and intensity combined with land-use change in watershed areas have led to increased soil erosion and siltation in rivers. This in combination with increased use of manure, chemical fertilizers, pesticides, and herbicides as well as atmospheric nitrogen deposition affects river chemistry and has led to eutrophication, with major implications for water quality, species composition, and fisheries.

High-latitude ecosystems in the Northern Hemisphere have been affected by regional climate change, in cases where for example extensive land areas in the Arctic show a 20th century warming trend in air temperature of as much as 5°C, in contrast to areas of cooling in eastern Canada, the north Atlantic, and Greenland. The warmer climate has increased growing degree-days by 20% for agriculture and forestry in Alaska, and boreal forests are expanding north at a rate equal to about 100 to 150 km per °C. Altered plant species composition, especially forbs and lichens, has been observed in the tundra.

4.1 Climate Change and Biodiversity in Europe



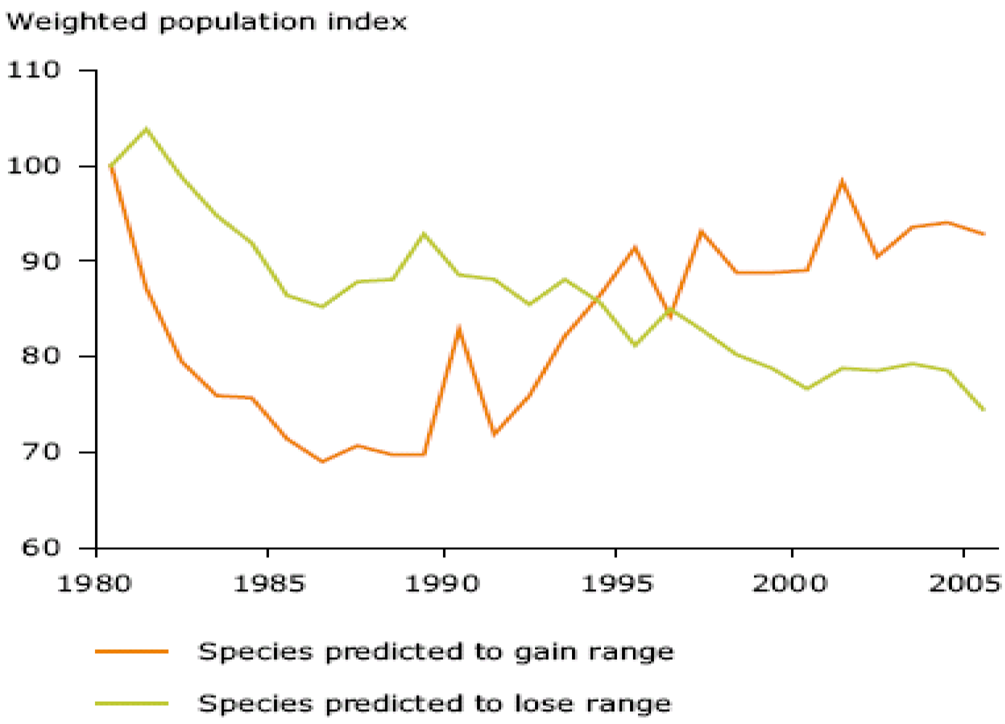
Note: Results for stable area per grid cell, using the EuroMove model with HadCM2 A2 climate scenario.

Source: Based on Bakkenes *et al.*, 2006.

The above map is based by a paper by Bakkenes *et al.* (2006) which used a model to predict plant species distribution for this century under different climate change scenarios. This study suggests that 10–50 % of plant species in European countries are likely to disappear by 2100 from their current location in the absence of climate change mitigation. Again, species in southeast and southwest Europe are likely to be worst affected. This number will be higher if migration is restricted due to continuing fragmentation or if there is competition with invasive species.

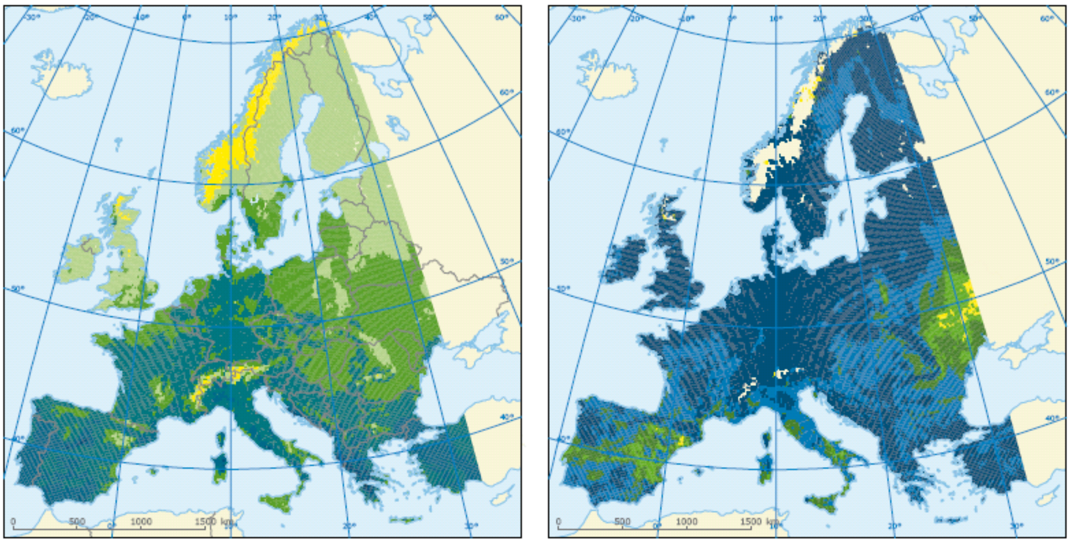
According to the EEA’s report on Impacts of Europe's changing climate — 2008 indicator-based assessment, Europe's birds, insects, mammals and other groups are moving northwards and uphill, largely in response to observed climate change. But rates of distribution change are not necessarily keeping pace with changing climate. A combination of the rate of climate change, habitat fragmentation and other obstacles will impede the movement of many animal species, possibly leading to a progressive decline in European biodiversity, and distribution changes are projected to continue. Suitable climatic conditions for Europe's breeding birds are projected to shift nearly 550 km northeast by the end of the century, with the average range size shrinking by 20%. Projections for 120 native European mammals suggest that up to 9% assuming no migration) risk extinction during the 21st century.

The following graph shows the impact of climate change on populations of European birds for the period 1980–2005.



According to Gregory et al. (2008), weighted composite population trends under climate change were modeled as an index for two groups of widespread European land birds for 1980 to 2005, using climate envelope models. The index is set to 100 in 1980. The orange line shows the modeled weighted composite trend of 30 bird species. It shows an increase of their geographical range in the study region. The green line shows the modeled trend of 92 species that have lost range. Range changes were modeled by averaging using three global climate models and two emissions scenarios.

A second study that follows shows the projected impact of climate change on the potential distribution of reptiles and amphibians in 2050 in Europe. According to Bakkenes, (2007), projected data based on the Generalized Linear Model map using the HadCM3 A2 scenario for the 2050s are compared with the current situation.



Potential changes in climate space of reptiles and amphibians in 2050

Current number of species

🟨 ▨ 🟩 🟩 🟦 🟦 🟦

0 1 10 20 30 40 50 60

Percentage of stable species in 2050

🟨 🟩 🟩 🟦 🟦

0 20 40 60 80 100

4.2. Climate Change and Biodiversity in Cyprus

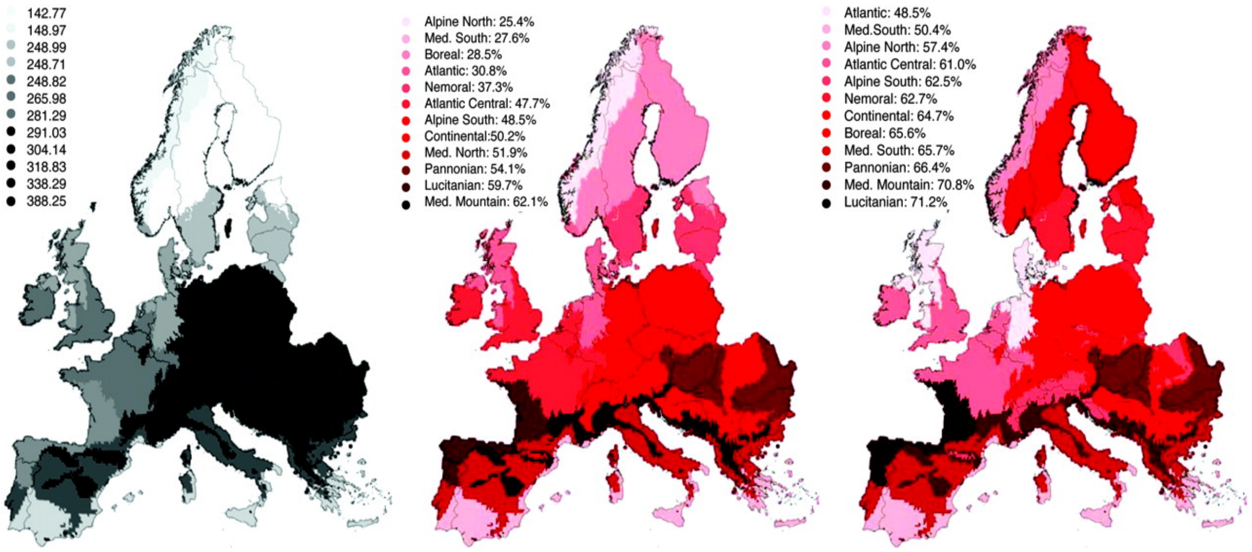
According to a report by the WWF (2005), the global 2 °C temperature rise is expected to be seasonally and spatially translated in the Mediterranean region, including Cyprus by:

- Largest increase in summer and inland temperature: mean temperature by 4 °C and maximum temperature by 5 °C, on average.
- Second largest increase in fall: 2-3 °C everywhere.
- Spring temperatures could rise by about 2 °C.
- Winter and spring temperatures could rise less than 2 °C.
- Although less pronounced, thanks to the sea, the rise in coastal region temperature is expected to be in the 1-2 °C range on average, and a bit more than 2 °C in summer for maximum temperature.
- Maximum temperature is expected to rise more than minimum temperature.

According to the study, there exist four types of regions:

- Inland: on average one additional month of hot days, and also one additional month of summer days.
- Along the coasts outside Central Mediterranean region: 1-3 weeks of additional hot days, and 2-3 weeks of additional summer days.
- The coastal regions in Central and Eastern Mediterranean region are expected to have only few additional hot days (like the other coastal regions), but one additional month of summer days, as in the continental part of the Mediterranean. Crete and Cyprus are perfect examples: no change in the number of hot days, but an average of 7 additional weeks of summer days.

Climate change over the past 30 years has produced numerous shifts in the distributions and abundances of species. Recent studies have tried to quantify future changes under different warming scenarios. Thuiller et al. (2005) shows that a 3.6°C global warming could lead to a loss of over 50% of plant species in the northern Mediterranean and the Mediterranean mountain region, while species loss is likely to exceed 80% in north central Spain and the Cevennes and Massif Central in France.

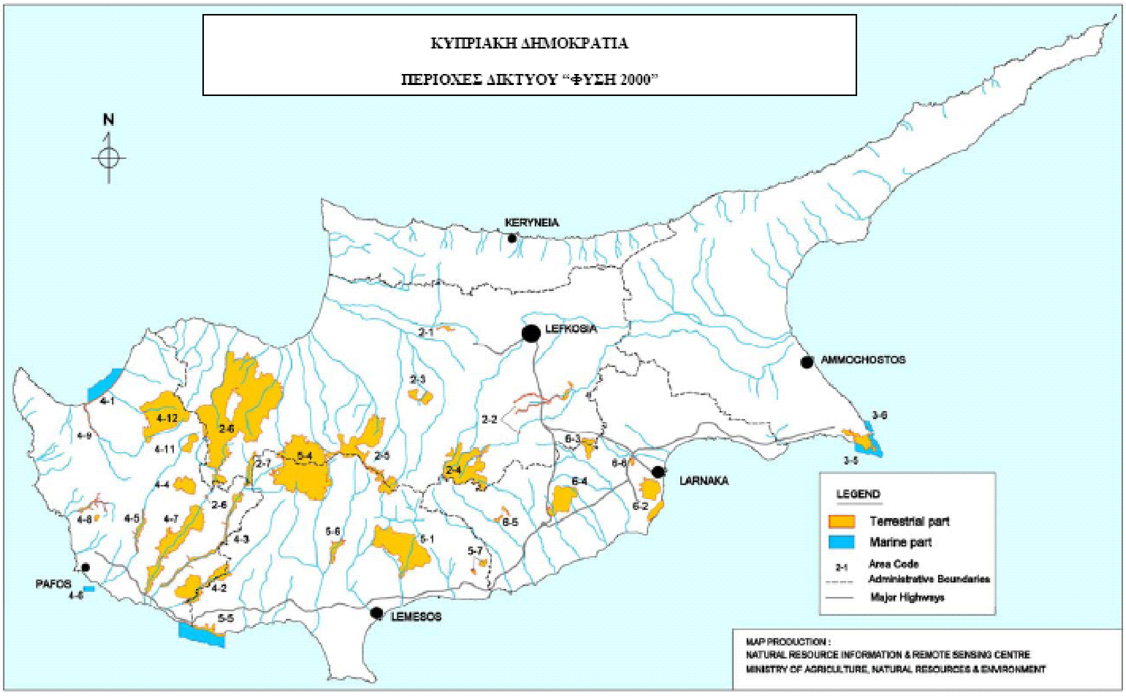


These results are in the direction of earlier studies (e.g., Thomas et al., 2004) although estimates of the magnitudes extinction risks are lower than earlier predictions. Climate change may also have indirect effects on the ecosystem. Grigulis et al. (2005) shows that increased fires due to climate change could increase the spread of invasive grass species which in turn, could lead to more frequent and more intense fires.

Cyprus, geologically as well as bio-geographically, is one of the most isolated islands of the Mediterranean. Due to its isolation, many local species are now considered as indigenous. Cyprus is a habitat to many important species (Tsindides, et al., 2007). Today, the fauna of Cyprus consists of 32 mammal species, 126 amphibians, 375 birds and a huge number of insects and other in vibrates. The largest mammal of Cyprus that can be found in its natural environment is the Cyprus mufflon (*Ovis orientalis ophion*), a rare species of wild sheep. From the 375 bird species which belong to 61 families, only 48 are permanent residents of the island, and 316 are migratory.

Generally, the local flora of Cyprus consists of 1610 species or 1738 taxa, whereas indigenous flora includes 238 taxa. A large number of flora (about 500) are considered rare, due to their small number of population. Some species are already considered extinct.

According to the report from the Environment Service regarding desertification (2008), there is serious observable trend of deterioration of flora and fauna of the island. One major factor is the decrease of soil fertility, due to water shortage, temperature increase and desertification phenomenon. Many species have serious decrease in populations up to a critical point, since their habitats have been shrinking during the last decades.



The above map includes all areas that are protected due to its biodiversity for Cyprus, terrestrial and marine areas, which according to the Environment Service of the Ministry of Agriculture, Natural Resources and Environment is about 18% of the total land cover of the island (www.moa.gov.cy) .

5. Climate Change - Time to Adapt!

Climate is changing! Climate change will heavily affect Europe's natural environment and nearly all sections of society and the economy. Europe has warmed by almost 1 degree in the last century, faster than the global average. There is widespread evidence that almost all natural, biological and physical processes (e.g. trees are blossoming earlier, glaciers are melting) are reacting to climate changes in Europe and worldwide. More than half of Europe's plant species could be venerable or threatened by 2080. The most vulnerable regions in Europe are:

- Southern Europe and the entire Mediterranean Region
- Mountain areas
- Coastal zones
- Scandinavia
- The Arctic region

Although there are some positive aspects of climate change (e.g. agricultural production in some limited parts of Europe - Yields in some northern regions of Europe could increase.), these are by far exceeded by negative impacts. The scientific evidence conveys the clear message that this change will impact the water cycle and water resources in Europe and worldwide. An increase in the frequency and intensity of extreme events such as floods and droughts is expected as well as long-term shifts in regional water balance and water availability. Both may have disastrous consequences for European societies. Changes in water resources will not only have significant adverse impacts on the drinking water supply and wastewater services in Europe, but also on other key economic activities such as agriculture, hydropower and other electricity production, tourism and navigation. These damaging effects will by far surpass minor benefits that may be experienced by individual regions or sectors. Ecosystems and biodiversity are likely to suffer from climate-driven changes in hydrology. Ecosystem services play a key role for human and economic activities, and their long-term protection and preservation should be given priority. Changes in climate will occur, even if climate protection measures are effectively implemented today. Although the magnitude and shape of climate change impacts on the water cycle and water resources cannot be predicted exactly, scientific evidence is sufficient to urge immediate action. Therefore, while climate change mitigation should remain a priority for policy-making, there is also an urgent need to develop strategies for adaptation to the already inevitable climate-change-driven changes in water resources at all levels of policy-making – from the European to national to local levels. There is now consensus on this among the science and policy communities.

Successful adaptation strategies have to follow a common and integrated approach that covers measures in all water-related sectors, in particular, in sectors that are strongly depending on the availability of clean and/or sufficient water, such as water supply, agriculture, electricity production, inland navigation and tourism. Such an approach will provide successful win-win solutions and avoid negative cross-sectoral feed backs of measures or non-action in one sector. It also allows including the preservation of aquatic and other water-dependent ecosystems, which is a prerequisite for developing effective adaptation strategies. Water needs to be used more efficiently across all sectors. Measures to be taken include water efficient irrigation techniques and water-saving appliances, reduced leakage in supply systems, and water recycling and rain water harvesting. Changes in behavior will be required and can be supported through adequate water pricing. At all policy levels, potential conflicts between sector policies and adaptation needs should be identified, and efforts should be made to make different policies consistent with each other and compatible with adaptation. As a consequence, adaptation to water-related climate change impacts is not just an issue for environment departments at all levels, but is also a challenge to other Directorates of the European Commission, national ministries, and regional and local government departments. In particular, local and regional authorities will need more practical guidance on how to cope with the local and regional impacts of climate change on water. On the other hand, local authorities can provide valuable information on measures that have been implemented already and help to identify best practice examples. Stakeholders at all levels have to be engaged in the process. Businesses and industries will have to develop their capacities to adapt. Also, adaptation efforts by private individuals will have to be bolstered in a variety of ways. Improved information and awareness of long-term perspectives, the necessity to adapt, and potential measures for adaptation are prerequisites for creating support for adaptation and for reaching agreement between different stakeholders on adaptation strategies. Participative approaches are necessary to enable the equitable use of water between different stakeholders and between upstream and downstream users. In order to encourage changes in the behavior of individuals and in order to ensure support for adaptation policy, it is vital to create a shared understanding of climate change impacts and adaptation through information, education and discussion processes.

Adaptation should be embedded in integrated water management approaches, which allow for a consideration of all environmental, economic and social aspects. Action is required at all levels – policy, implementation and operational. Decision-making under uncertainty is a particular challenge. Water management and the implementation of water policy needs to be capable to respond to unexpected developments caused by climate change. Strategies for adaptation need to be developed and implemented in a flexible way, in order to take into account further progress of scientific knowledge. Special emphasis should be placed on “no-regret” and “win-win” measures that are effective and sustainable under different scenarios. For adaptation it may be necessary to define priority water uses and to find appropriate ways to implement prioritization. Choices may have to be made concerning the allocation of water resources, and criteria and indicators need to be developed on the basis of which such choices can be made. The water sector (water supply and sanitation services) will have to work on combined supply and demand side measures. This could include legal, regulatory and contractual requirements that foster implementation and an equitable repartition of costs among users, providers and polluters. Reducing vulnerability to extreme weather events is key for adaptation, and both disaster prevention and response measures need to be part of strategies and approaches. Appropriate risk assessment for building development is essential to avoid the accumulation of assets in high risk areas, for instance in floodplains and along the coast. Flexible water management systems that can react to both water scarcity and flood situations may be helpful instruments.

Agriculture has a high potential for mitigation (e.g. appropriate production of biofuels, carbon sequestration) and adaptation to climate change (e.g. diversification and adjusted management schemes as shifts to new crops and shifts in cropping seasons). Agriculture needs to address the double challenge of reducing its GHG emissions while at the same time adapting to projected impacts of climate change. Agriculture releases GHGs into the atmosphere, though on a smaller scale than other economic sectors. Agriculture can also help provide solutions to the EU‘s overall climate change challenges. Agriculture is an important source of two powerful greenhouse gases: nitrous oxide (N2O) and methane (CH4). N2O is released to the atmosphere mainly due to the microbial transformation of nitrogen fertilizers in soils; the generation of N2O represents over half the total emissions from agriculture; CH4 emissions come mainly from intestinal fermentation by ruminant animals (enteric fermentation); Both N2O and CH4 emissions are produced from manure storage – decomposition of stored manure in oxygen deprived conditions – and spreading on farmland. Agriculture hardly emits carbon dioxide (CO2) – the most widespread GHG in the atmosphere. On the contrary, agricultural lands, which occupy over half of the EU's territory, hold large carbon reserves that help reduce CO2 in the atmosphere. The changing climate is also a major challenge for agriculture and agricultural policy-making.

Planning for adaptation in agriculture should also consider effects on mitigation and vice versa. Forests and forestry also play an important role both for mitigation and adaptation, and need to be considered in climate policies and strategies as well. Agricultural water use has to be optimized, especially in central and southern European water-scarce regions. Northern regions will face an increase in nutrient losses and erosion due to increased precipitation, with negative impacts such as eutrophication of aquatic ecosystems. These impacts can be tackled by regional planning, landscape design and farming techniques. Agriculture can - through adapted land use management and changing to less water demanding crops - contribute to securing water resources (i. a. increase of ground water recharge), protecting water resources (less nutrient loss) and to improving flood management. There is certainly scope for improving the adaptive capacity of European agricultural systems through the funding schemes provided by the Common Agricultural Policy (CAP) of the EU. Adaptive capacity might benefit from realizing full de-coupling of payments. Rural development funding, provided under the second pillar of the CAP, can be used to directly support measures aimed at adaptation, such as the development of new products, processes and technologies that are more adaptive or measures on education and advice. While many climate change problems linked to agriculture are being addressed by developments in farming structures and management techniques, this is taking place within a regulatory environment that sets limits on some practices. Various items of EU legislation contribute greatly to mitigating climate change, for example the Nitrates Directive (see environmental legislation box).

Box 3. Environmental legislation

The following are examples of environmental legislation which, although not addressing climate change directly, are relevant to the avoidance of GHG emissions in the agricultural sector:

Nitrates Directive (Council Directive 91/676 of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources, OJ L 375 of 31.12.1991) – the Directive has two main objectives: to reduce water pollution by nitrates from agricultural sources and to prevent further pollution. The Directive is managed by Member States and involves: monitoring of water quality in relation to agriculture; designation of nitrate vulnerable zones; establishment of (voluntary) codes of good agricultural practice and of (obligatory) measures to be implemented in Action Programmes for the nitrate vulnerable zones. Several Member States have designated their whole territory as vulnerable to nitrate pollution. For these zones, the Directive also establishes a maximum limit of nitrogen from livestock manure that can be applied per hectare: 170 kg N/ha per year. Codes of good agricultural practice cover such activities as application periods, fertiliser use near watercourses and on slopes, manure storage and spreading methods and crop rotation and other land management measures.

Integrated Pollution Prevention and Control (IPPC) Directive (Council Directive 96/61 of 24 September 1996 concerning integrated pollution prevention and control, OJ L 257, 10.10.1996) – the Directive aims at minimizing environmental pollution and nuisance from large operations/installations. The IPPC Directive covers livestock farms with more than 2 000 fattening pigs and/or more than 750 sows and/or more than 40 000 chickens. Measures that must be applied on those farms are mainly aimed at reducing ammonia emissions (e.g. covered storage of animal manure, improved housing systems, air purification, manure handling and treatment, low-emission manure application). Ammonia is not a greenhouse gas, but the measures concerning manure treatment also influence methane and nitrous oxide emissions. In 2006, the Commission launched a review process of the IPPC Directive that aims to improve its implementation further.

National Emission Ceilings Directive (NEC) (Directive 2001/81 of 23 October 2001 on national emission ceilings for certain atmospheric pollutants, OJ L 309, 27.11.2001) – the NEC Directive, operates within the EU's overall air quality policy, and sets upper limits for each Member State for the total emissions in 2010 of the four pollutants responsible for acidification, eutrophication and ground-level ozone pollution (which includes ammonia). It is left largely to the Member States to decide which measures to take in order to comply. Member States are obliged to draw up national programmes to demonstrate how they will meet the national emission ceilings by 2010.

Water Framework Directive (WFD) (Directive 2000/60 of 23 October 2000 establishing a framework for Community action in the field of water policy, OJ L 327, 21.12.2000) – the overall objective of the WFD is to establish a framework for the protection of all waters (surface water and groundwater), in particular to prevent further deterioration and to protect the status of ecosystems and wetlands and to promote sustainable water use, and to contribute to mitigating the effects of floods and droughts. Member States are responsible for the designation of river basins and the preparation of river basin management plans, including programmes of measures. WFD is also a tool to address pressures from farming activities on water quality and quantity, with a link to climate change mitigation and adaptation.

Soil Framework Directive (proposed). Soil performs many functions, including that of a carbon sink. It therefore contributes to climate change mitigation. The EU is trying to improve soil protection and has proposed a regulatory framework. Member States' obligations under the proposed Directive are to identify (within five years) areas at risk of soil degradation, to specify (within seven years) risk reduction targets for these areas and to establish programmes of measures, which have to be put in place within eight years from adoption of the Directive. The proposed Directive is in the EU decision-making process. The Directive will allow Member States to set acceptable levels of soil erosion (for example), within the overall objectives of the Directive.

The 17th session of the United Nations Commission on Sustainable Development (CSD-17) has made important steps forward in the international sustainable development agenda. The outcome document "policy options and practical measures to expedite implementation in agriculture, rural development, land, drought, desertification and Africa" was adopted with consensus. It focuses on the opportunities and the challenges faced by our global agricultural system and, especially its importance to the developing world. The role of agriculture is redefined. Agriculture is not longer part of the problem, but part of the solution. During CSD-17 the relation between agriculture and climate change was specifically highlighted, especially regarding mitigation measures. Sustainable agriculture can contribute to mitigation of climate change with measures such as producing green commodity chains, sequestration of CO2 in soils and livestock and manure management. Agriculture and rural development play a vital role in the bio-based economies of the future. On the other side, climate change and even some measures that respond to it will have effects on the agricultural production and ecosystems, with consequences for the poor populations. The negative impact of climate change on Africa was underlined at CSD-17. Adaptation measures in agriculture such as water management, development of alternative production systems and sustainable land use can reduce vulnerability to climate change. In addition, climate change will, over the next few decades, force farmers, conservationists and water managers to respond to competing, and often conflicting, pressures. Land managers will need to increase food production, grow bio-fuels, conserve biodiversity, and maintain carbon stocks in soil and forests. The outcome of CSD-17 underlines that agriculture is at the heart of the climate change agenda. Therefore agriculture should play a more central role in the mitigation and adaptation of climate change and the outcome of COP15 in Copenhagen. This could be done along the following lines:

- Comprehensive low carbon development strategies by developing countries, except the least developed, covering key emitting sectors including the agricultural sector, should be the basis for the contribution of developing countries to the global mitigation effort and a pathway to access to financial and technical support from developed countries.

- Rules for the treatment of land use in the context of the Kyoto Protocol and the follow up thereof via an integrated approach for land use;

- International cooperation in the area of research and technology for mitigation in agriculture;

- Organizations like the Food and Agriculture Organization (FAO) and the CGIAR Climate Change Program have expertise to prepare and implement such measures.

Climate change adaptation activities can promote conservation and sustainable use of biodiversity and reduce the impact of changes in climate and climatic extremes on biodiversity. These include the establishment of a mosaic of interconnected terrestrial, freshwater, and marine multipleuse reserves designed to take into account projected changes in climate, and integrated land and water management activities that reduce non-climate pressures on biodiversity and hence make the systems less vulnerable to changes in climate. Some of these adaptation activities can also make people less vulnerable to climatic extremes.

The effectiveness of adaptation and mitigation activities can be enhanced when they are integrated with broader strategies designed to make development paths more sustainable. There are potential environmental and social synergies and tradeoffs between climate adaptation and mitigation activities (projects and policies), and the objectives of multilateral environmental agreements (e.g., the conservation and sustainable use objective of the Convention on Biological Diversity) as well as other aspects of sustainable development. These synergies and tradeoffs can be evaluated for the full range of potential activities—inter alia, energy and land-use, land-use change, and forestry projects and policies through the application of project, sectoral, and regional level environmental and social impact assessments—and can be compared against a set of criteria and indicators using a range of decision making frameworks. For this, current assessment methodologies, criteria, and indicators for evaluating the impact of mitigation and adaptation activities on biodiversity and other aspects of sustainable development will have to be adapted and further developed.

Scientific results and research will play a crucial role for enabling and facilitating adaptation processes. Through further research, more detailed information will become available on the impacts of climate change on the water cycle, in particular with respect to issues that are still subject to major uncertainties, such as future changes in the frequency and magnitude of extreme events. Research will also provide essential contributions to the identification of the most adequate adaptation measures and strategies, for instance by investigating economic and cost aspects. To ensure that research generates information that is suitable and useful for adaptation, scientists and practitioners activities. Further research activities are necessary and should focus in particular on:

a. Better understanding and quantification of uncertainty throughout the chain of "emissions → climate change→ physical impact → ecological impact → socio-economic impact" and improving the communication and handling of uncertainty in political decision making processes.

b. Better understanding and quantification of economical and social impacts of climate change in the different sectors.

c. Further improving and linking climate, hydrological, bio-physical and socio-economic models to better understand the complexity of the water cycle and aquatic ecosystems and how these will react to climate change. Since projections of changes at regional or river basin level will be most relevant for adaptation, the downscaling of models to lower scales needs to be a focus of future research.

d. Identifying thresholds and points of no return beyond which recuperation of the water resources and the water dependent systems is no longer possible.

e. Options for adaptation strategies, which integrate sectoral and cross-sectoral measures, and the assessment of their ecological, social and economic potential, benefits and costs.

f. Interdisciplinary approaches will be key, and attention should be given to the design of organizational structures that increase the capacity of water management to adapt to climate change.

g. Establishing of a solid baseline for evaluating Member State's adaptation plans, based on a historical archive of climatology

While developing their own adaptation strategies, the EU and its Member States should not forget about the urgent need to support adaptation in the developing world, since these countries will be most strongly affected by the impacts of climate change. Adaptation should be mainstreamed into the EU's development co-operation and assistance schemes, such as those for Africa and the EU neighborhoods countries. International programs and activities aiming at the development and improvement of adaptation measures should be supported. Measures that may help developing countries to cope with climate change impacts include monitoring and prediction of climate change impacts on water and water uses, risk management, access to climate change risk insurance markets, preparedness and disaster response, methods to avoid and combat further land degradation, and development of more resistant food crops. Such efforts are particularly important in cases where current resource conflicts might be exacerbated by climate change impacts.

REFERENCES

Arnell, N. W., 2004. Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environmental Change* 14: 31–52.

Alcamo.J; Flörke, M. and Märker, M., 2007. Future long‑term changes in global water resources driven by socio-economic and climatic change. *Hydrological Sciences Journal* 52: 247–275.

Bakkenes, M.; Eickhout, B. and Alkemade, R., 2006. Impacts of different climate stabilisation scenarios on plants species in Europe. *Global Environmental Change* 16: 19–28.

Bakkenes, M., 2007. Produced for the EEA by Netherlands Environmental Assessment Agency (PBL), based on data of the ALARM project (http://www.alarmproject.net.ufz.de).

Birsan, M. V.; Molnar, P.; Burlando, P. and Pfaundler, M.,2005. Streamflow trends in Switzerland. *Journal of Hydrology* 314: 312–329.

Bongaarts, J., 1994. Can the growing human population feed itself? *Scientific American* 270 (3): 18–24.

C. Giannakopoulos, M. Bindi, M. Moriondo, P. LeSager and T. Tin, Climate change impacts in the Mediterranean resulting from a 2oC global temperature rise. A report for WWF, 1 July 2005

Dankers, R.; Feyen, L., 2008b. Climate change impact on flood hazard in Europe: An assessment based on high resolution climate simulations. Manuscript submitted to Journal of Geophysical Research Atmospheres.

Dixon, H.; Lawler, D. M. and Shamseldin, A. Y., 2006. Streamflow trends in western Britain. *Geophysical Research Letters* 23: L19406, DOI:10.1029/2006GL027325.

EEA Report No 4/2008, Impacts of Europe's changing climate — 2008 indicator-based assessment Joint EEA-JRC-WHO report.

Environment Service, Ministry of Agriculture, Natural Resources and Environment, National Action Plan for Desertification, 2008.

EU European Commission Directorate-General for Agriculture and Rural Development, Fact Sheet – The challenges of climate change to agriculture, 2008.

Gregory, R. D.; Willis, S. G.; Jiguet, F.; Voříšek, P.; Klvaňová, A.; van Strien, A.; Huntley, B.; Collingham, Y. C.; Couvet, D. and Green, R. E., 2008. An indicator of the impact of climatic change on European bird populations (in press).

Grigulis, K., Lavorel, S., Davies, I.D., Dossantos, A., Lloret, F. and Vilà M., Landscape-scale positive feedbacks between fire and expansion of the large tussock grass, Ampelodesmos mauritanica in Catalan shrublands, Global Change Biology (2005) 11, 1–12.

Hisdal, H.; Stahl, K.; Tallaksen, L. M. and Demuth, S., 2001. Have droughts in Europe become more severe or frequent? *International Journal of Climatology* 21: 317–333.
Hisdal, H.; Holmqvist, E.; Kuusisto, E.; Lindström, G. and Roald, L. A., 2007. Has streamflow changed in the Nordic countries? *Climate Research*, submitted.

IPPC, 2002, "Climate Change and Biodiversity", United Nations Convention on Biological Diversity and prepared under the auspices of the IPCC Chair, Dr. Robert T. Watson.

IPCC, 2007: Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds.)]. Cambridge University Press, Cambridge, United Kingdom, 1000 pp.

Kundzewicz, Z. W.; Budhakooncharoen, S.; Bronstert, A.; Hoff, H.; Lettenmaier, D.; Menzel, L. and Schulze, R., 2002. Coping with variability and change: floods and droughts. *Natural Hazards Forum* 26: 263–274.

Lindström, G. and Bergström, S., 2004. Runoff trends in Sweden 1807–2002. *Hydrological Sciences Journal* 49 (1):69–83.

Malcolm, J. R., Markham, A., Neilson, R. P., and Garaci. M. 2005. Case study: migration of vegetation types in a greenhouse world. Pp. 252-255 In: Climate Change and Biodiversity (T. E. Lovejoy and L. Hannah, eds.), Yale University Press, New Haven.

Menzel, A.; Jakobi, G.; Ahas, R.; Scheifinger, H. and Estrella, N., 2003: Variations of the climatological growing season (1951–2000) in Germany compared with other countries. *International Journal of Climatology* 23: 793–812.

Meleux, F.; Solmon, F.; Giorgi, F., 2007. Increase in summer European ozone amounts due to climate change. *Atmospheric Environment* 41 (35): 7577–7587.
National Sustainable Development Strategy, Ministry of Agriculture, Natural Resources and Environment, Environment Service, Cyprus.

Milly, P. C. D.; Dunne, K. A. and Vecchia, A. V., 2005. Global pattern of trends in streamflow and water availability in a changing climate. *Nature* 438: 347–350.

Parmesan, C., & G. Yohe 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421:37-42

Reilly, J.; Patsev, S.; Felzer, B.; Wang, X.; Dicklighter, D.; Melillo, J.; Prinn, R.; Sarofim, M.; Sokolov, A. and Wang, C., 2007. Global economic effects of changes in crops, pasture, and forests due to changing climate, carbon dioxide, and ozone. *Energy Policy* 35 (11): 5370–5383.

Statistical Service, data for 2003,
http://www.pio.gov.cy/mof/cystat/statistics.nsf/agriculture_en/

Stuyfzand P. J.; Ruediger, R. L and Kristensen, P., 2007. *Impact of climate change on groundwater*. A background note for EEA produced by the EEA ETC/Water.

Thomas C.D. and 18 others. 2004. Extinction risks from climate change. Nature, 427, 145–148.

Thuiller W., Lavorel S., Araújo M.B., Sykes M.T. and Prentice I.C. 2005. Climate change threats to plant diversity in Europe. PNAS 102 (23), 8245–8250.

T. Tsindides, C.S. Christodoulou, P. Delipetrou, K. Georgiou (2007) «The Red Book of Cyprus»

UNEP, Working Group II, "Climate Change 2007, Impacts, Adaptation and Vulnerability", IPPC 2007.

Wade, S.; Vidal, J.-P.; Dabrowski, C.; Young, P. and Romanowicz, R., 2005. Effect of climate change on river flows and groundwater recharge. A practical methodology. Trends in UK river flows: 1970–2002. UKWIR Report 05/ CL/04/5.

Wang, W.; Van Gelder, P. H. A. J. M. and Vrijling, J. K., 2005. Detection of changes in streamflow series in western Europe over 1901–2000. Water Science and Technology: Water Supply 5 (6): 289–299.

Werritty, A., 2002. Living with uncertainty: climate change, river flows and water resource management in Scotland. The Science of the Total Environment 294: 29–4

www.moa.gov.cy – Ministry of Agriculture, Natural Resources and Environment, Environment Service, Cyprus.

http://www.ipcc-wg2.org/index.html

http://www.epa.gov/climatechange/effects/water/availability.html

http://www.epa.gov/climatechange/effects/water/quality.html

http://ga.water.usgs.gov/edu/watercyclesummary.html

The climate dataset is from the EU-FP6 project ENSEMBLES http://www.ensembles-eu.org and the data providers in the ECA&D project http://eca.knmi.nl

The climate dataset is from the EU-FP6 project ENSEMBLES http://www.ensembles-eu.org and the data providers in the ECA&D project http://eca.knmi.nl

Based on data from Dartmouth Flood Observatoryhttp://www.dartmouth.edu/~floods/

Ministry of Agriculture, Natural Resources and Environment
http://www.moa.gov.cy/moa/agriculture.nsf/index_en/index_en?OpenDocument
Water Development Department, Cyprus
http://www.moa.gov.cy/moa/wdd/Wdd.nsf/index_en/index_en?OpenDocument
Meteorological Service, Cyprus
http://www.moa.gov.cy/moa/MS/MS.nsf/DMLcyclimate_en/DMLcyclimate_en?opendocument
http://www.ipcc.ch/pdf/technical-papers/climate-changes-biodiversity-en.pdf
http://www.climate-water-adaptation-berlin2007.org/documents/conclusions.pdf
http://www.un.org/esa/dsd/csd/csd_csd17.shtml
http://www.ceja.org/downloads/S/Seminars/2007/Campania,%20Italy/CEJA-N-105-2007 EN_Green_Paper_Climate_Change.pdf