


Climate change  
and impacts  
in the **Eastern  
Mediterranean and  
the Middle East**



THE CYPRUS  
INSTITUTE

A regional climate  
assessment by **the  
Cyprus Institute**



The predicted  
warming and drying  
of the region will have  
major consequences

## Contents

- 02** Summary
- 04** Present climate conditions
- 05** Climate of the past half millennium: A history of change
- 06** Future projections of climate change: A hot dry future
- 07** Air pollution and desert dust: Changes to air quality
- 08** Human health concerns
- 09** Land ecosystems and agriculture
- 10** The Mediterranean Sea: Changes to marine ecosystems
- 11** Changes to freshwater resources
- 12** Energy demand



## Summary

The Eastern Mediterranean and the Middle East (EMME) is made up of two dozen countries with over 400 million inhabitants spread over an area with a 2,000 km radius. After years of intense industrialisation, rapid population growth and extensive land conversion, the EMME has now become a global climate change 'hot spot'.

### Predicted climate changes

To understand the implications of EMME's shifting weather patterns, researchers have projected climate change for the 21st Century, using a regional climate model based on an intermediate emission scenario, and predicted impacts on the environment. The research suggests substantial regional climate changes, with significantly dryer and warmer conditions.

### Increasing temperatures

There is expected to be a continual and gradual warming of temperatures, with highest rates in the north of the EMME. The mean temperature rise will be about 1-3°C in the next three decades, 3-5°C by mid-century and 3.5-7°C by the end of the century. This is increasing at about  $0.37 \pm 0.9^\circ\text{C}$  per decade, which suggests that the region is likely to warm at a much faster rate than the global mean rate of 2.8°C by the end of the century.

In addition, there are likely to be extremely high summer temperatures.

### Decreasing rain

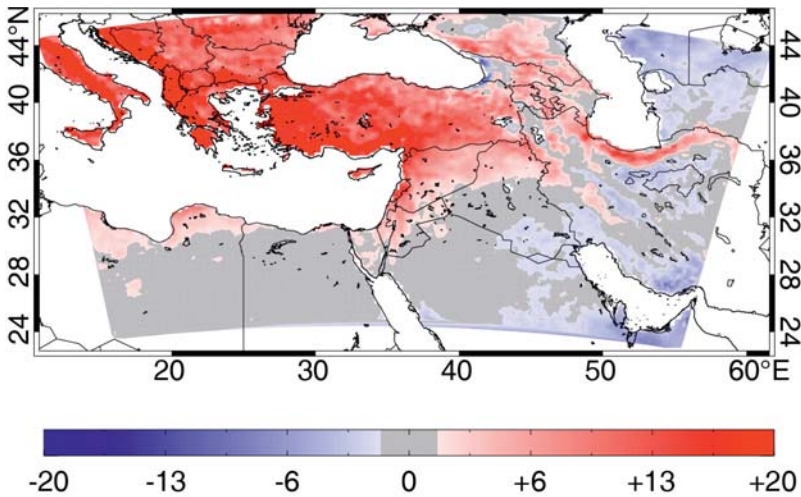
The precipitation throughout the EMME region is expected to decline. In the north a decrease of 10-50% during the 21<sup>st</sup> Century is expected, with rainfall primarily decreasing in spring and summer. In the south, precipitation may actually increase due to the expanding influence from the humid tropics, though this is modest in absolute terms.

### Impacts of the expected changes

The predicted warming and drying of the EMME region will have major consequences for both humans and natural ecosystems, especially from the increased heat stress and reduced rainfall.

### Impacts on air quality

Air quality is expected to decline in the EMME. In the north, increasing dryness will lead to escalating vegetation fires and resulting pollution emissions. The EMME has several megacities in which air quality is already seriously degraded and ozone levels are expected to continue to increase. As a result, air quality control measures are considered to be critical.



Changing number of dry days/year by mid-century

### Impacts on human health

There is compelling evidence that the maximum daytime temperatures in the EMME are increasing especially rapidly, which will lead to extended heat waves with major consequences for city dwellers. In addition, vector-borne parasitic and viral diseases are expected to increase in prevalence. Although increasing temperatures promote the spreading of vector organisms, hosts and infectious diseases, it will be necessary to consider climate change in combination with other influences.

### Impacts on land ecosystems and agriculture

The EMME has a high biodiversity due to its large gradients in topography and soil fertility, and the varied climate. The predicted drying and warming of the EMME has the potential to dramatically alter the balance of species in the region. Projections suggest that the milder winters in the north will be associated with a lengthening of the growing season, which could positively influence agriculture. However, this will likely be overshadowed by the increasing number of hot days and the decreasing soil moisture.

### Impacts on marine ecosystems

The marine ecosystems of the Mediterranean Sea are already affected by climate-driven and other human-induced changes. There

is expected to be a warming of water temperature, increasing salt content and resulting in water mass stabilisation and an expected sea level rise of about 1.3-2.5 cm per decade. The marine biodiversity will be affected by decreased nutrient availability, marine ecosystems becoming more 'tropical' and the invasion of alien species.

### Impacts on freshwater resources

Parts of the EMME, especially in the Middle East, are already notorious for fresh water scarcity. The predicted decreasing rainfall will result in a river discharge decrease of 10-30% by the end of the 21<sup>st</sup> Century and a significant reduction in the availability of freshwater for the EMME, with important social and economic implications, especially in agricultural areas. The region will need to invest in desalination and improved water-use efficiencies.

### Impacts on energy demand

Fossil fuels dominate the energy supply in the EMME and this use is growing at one of the highest rates in the world. During the warm season the demand for air conditioning is expected to increase significantly. This energy demand will grow in parallel with water deficits, which additionally places pressure on energy production. Alternative sources of energy and improved energy efficiencies are therefore critical for the EMME region.



Extended heat waves will have major consequences for city dwellers

# Present climate conditions

## The region's climate

The EMME region finds itself at a crossroads of global climatic patterns. There is a convergence of different maritime conditions over the region, extensive adjacent land masses transporting continental air and extreme differences in topographical features, all of which gives EMME its diverse climate.

## The importance of global linkages

The countries within the EMME are influenced by many of the key weather tele-connections (linkages of weather anomalies over great distances). One of the most prominent is the North Atlantic Oscillation (NAO), which is a large scale rearrangement of atmospheric air masses. The El Niño/Southern Oscillation (ENSO) also influences the EMME's climate, as El Niño brings dry conditions mainly to the western countries.

Apart from the remote and indirect climate effects NAO and ENSO bring, the EMME's weather is directly influenced by the Red Sea

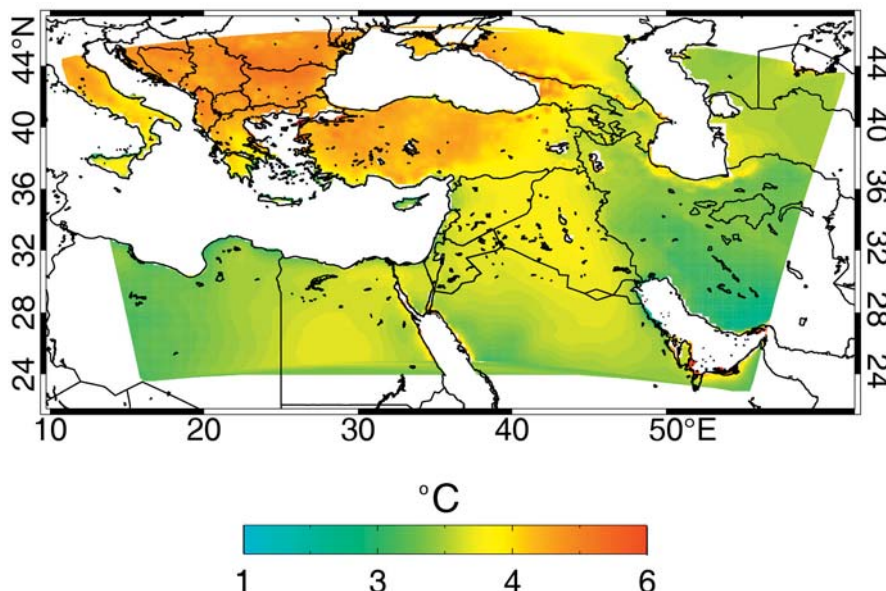
troughs, tropical intrusions and dust storms from the Sahara desert. The region is also impacted by the massive South Asian monsoon and all the different climatic processes that control it. This monsoon creates large-scale subsidence over the central and eastern Mediterranean, reducing convection and producing clear skies.

## Extreme weather conditions

The current climate experienced throughout the EMME is already fairly extreme with temperature and precipitation changing rapidly across the region. The northern EMME enjoys a temperate climate with warm and hot dry summers, occasional droughts and mild, relatively wet winters. For the southern EMME there is little rainfall and as a result these countries encounter an arid and hot desert-like climate. Since the EMME region already experiences hot climatic conditions with varying temperatures and droughts, there is much concern that any impacts resulting from climate change in this region will have disproportional effects compared to other areas.



*Increasing daytime summer temperature by mid-century*





# Climate of the past half millennium: A history of change

## Climate pre-1960

In the EMME the seasonality of rainfall is of major importance to the pre-1960 climate, with most falling in winter. There is an obvious northwest-southeast gradient in the amount of winter precipitation. More pronounced wetter and drier periods can also be identified in the pre-20<sup>th</sup> Century period.

Summer temperatures from 1500 to around 1900 were not distinctly lower than recent levels. The early 20<sup>th</sup> Century is characterised by a strong increase in summer mean temperature until around the 1950s when a cooler period began. The records clearly indicate reduced climate variability prior to the early 19<sup>th</sup> Century.

## Climate post-1960

The annual mean temperature in the EMME region since 1960 ranges from about 0°C in mountainous areas to about 15°-17°C in northern coastal parts. The southern part of the region has a notably different regime with

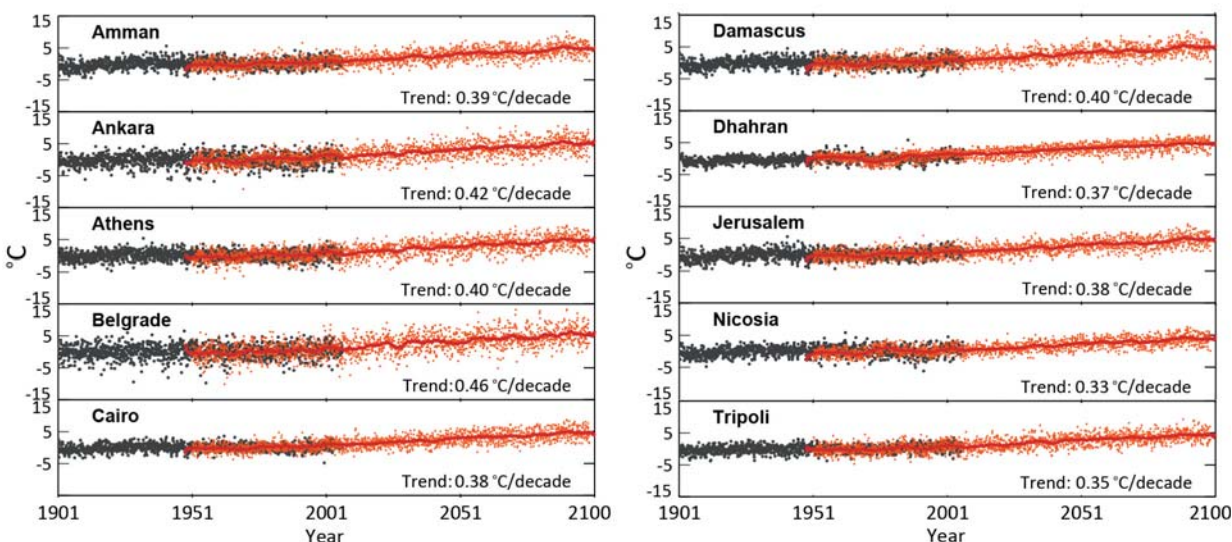
a mean temperature range of 18° to 28°C. An exceptionally strong, unprecedented warming period is experienced since the mid-1970s, which includes the hottest summer ever recorded in 2003.

The most pronounced post-1960 climatic patterns within the EMME are related to rainfall, regulated by major weather systems. The large north-south contrast is evident in both annual and seasonal rainfall patterns. In the northern EMME the average total annual precipitation between 1961 and 1990 ranges from approximately 500 mm in the east to more than 1,000 mm in the west.

For most of the region, summer is the dry season. In the southern part of the EMME, rainfall deficits and summer dryness are commonplace. The dominance of differences in topography is evident from the localised high winter precipitation levels. There is also clear evidence of a strong drying trend starting in the early 1960s with the lowest precipitation rates being recorded in the late 1990s.

There is clear evidence of a drying trend starting in the 1960s

Observed (black) and model calculated (red) temperature trends





## Future projections of climate change: A hot dry future

### Rising temperatures

Research predicts that the temperature in the EMME is likely to increase between 2-4°C in winter and 2-6°C in summer over the coming century. The warming across the region will be gradual; ranging from 1-3°C in the next three decades, to 3-5°C in the mid-21<sup>st</sup> Century and to 3.5-7°C by the end of the century.

### Declining rainfall

Overall rainfall is predicted to decrease by 20-30% throughout the EMME over the course of the 21<sup>st</sup> Century, although some areas will see localised though modest increases. In addition, extended periods of more severe droughts are expected in the Mediterranean. Precipitation may significantly decrease in winter along the eastern Mediterranean coast by between 30-50%, although elsewhere in the south-eastern Middle East there may be increases, though modest in absolute terms considering the small annual rainfall. In summer, the EMME drying is also significant and the areas that will experience winter

rainfall increases are expected to become drier in the summer.

### More hot days and nights

The overall heat stress in the EMME region is expected to be significant in the future with a remarkably large increase in the number of hot days per year. The biggest increase appears over the Levant and along the North African coast. It is expected that hot nights will gradually increase starting in the south of the EMME and progressing north. The increase in the number of days with hot nights warmer than 25°C by more than 2 months per year is of particular concern.

### Impacts on society and the economy

In summer, climate change is expected to intensify heat waves and this has major implications for human health, energy use and economic activity. The Middle East has been identified as the first region worldwide to effectively run out of fresh water and access to drinking water will become a critical issue as parts of the EMME essentially dry out.

# Air pollution and desert dust: Changes to air quality

## Increasing fine aerosol particles

There are already high levels of air pollution in the EMME region, both of natural and anthropogenic origin. The fine aerosol particles are mostly composed of sulphates and particulate organic matter, whereas the coarser particles are dominated by desert dust. The levels of fine aerosol particles in the EMME region are expected to rise substantially during the mid-21<sup>st</sup> Century due to increasing emissions of sulphur dioxide and nitrogen oxides.

## Increasing ozone smog

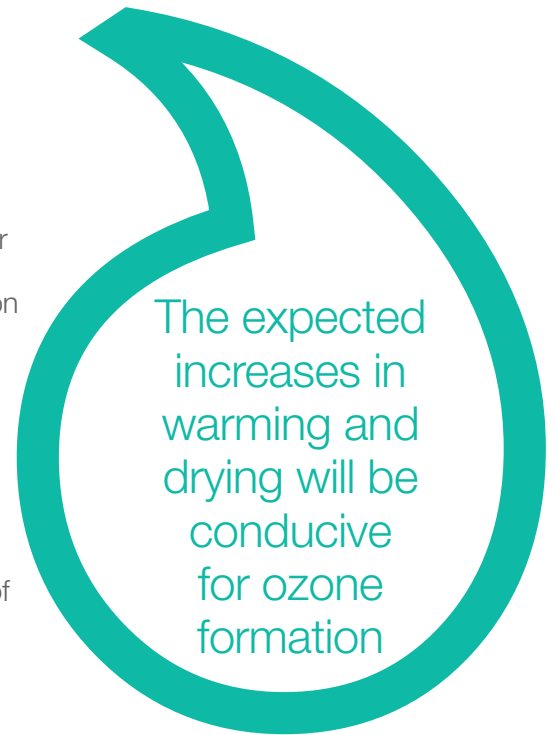
In summer the EMME is largely cloud-free, and the relatively intense solar radiation promotes the formation of ozone. In the Mediterranean region, ozone levels often exceed air quality limits, particularly in summer, and the Mediterranean ozone levels are among the highest in the world. It is likely that ozone levels will continue to increase and that the EMME will be a persisting air pollution 'hot spot' with especially high levels around the Persian Gulf.

## Impacts of megacities

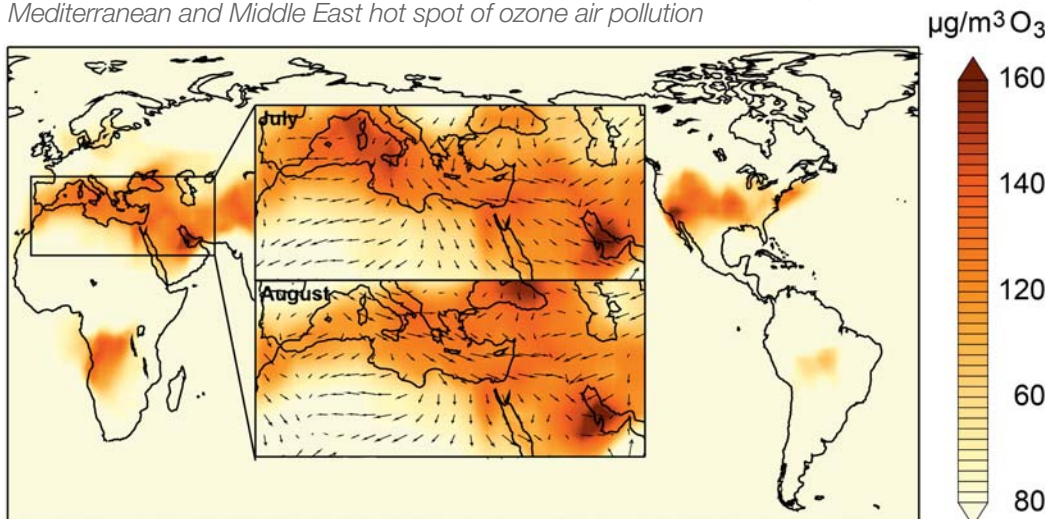
Megacities have become a common phenomenon in the EMME and are a major contributor to air pollution emissions. Since population growth and urbanisation in the southern and eastern parts of the EMME will likely continue, the situation of poor air quality is expected to aggravate until appropriate measures are implemented. It is anticipated that in the long-run, however, traffic emissions will stabilise and could possibly decrease by the middle of the 21<sup>st</sup> Century.

## Impacts of climate change on air quality

The effects of climate change on pollutant concentrations are rather uncertain. Overall, emission controls (or the lack thereof) are considered to have a stronger influence on air quality than climate and land-use changes. In future, the expected increases in warming and drying will be conducive for ozone formation, especially during heat spells, and this can have major consequences for air quality within the EMME.



Mediterranean and Middle East hot spot of ozone air pollution





# Human health concerns



There is growing evidence that public health in the EMME region is already being affected by the changing climate, and this is expected to increase in severity.

## Increasing frequency of heat waves

Children and the elderly suffer disproportionately from extreme temperatures, and the urban populations are particularly vulnerable. Heat waves can also increase air pollution concentrations and it is highly probable that heat waves will become more common in the EMME. The predicted increase in occurrence of hot nights in the southern EMME will exacerbate the heat stress and the associated health issues.

## Increasing vector-borne infectious diseases

After several decades of steady decline in vector-borne parasitic and viral diseases throughout the EMME region, a recent upsurge of these diseases has occurred. Vector-borne diseases are now spreading northward from Africa and have become an emerging threat in the EMME.

- Malaria – This is considered to be a highly climate-sensitive tropical

disease. However, the spread of Malaria cannot be related to a single cause and it will be necessary to study the links between seasonal temperature, rainfall and the vector distribution

- West Nile Fever – The occurrence of this virus is connected to climatic factors, particularly where heat stress is enhanced by high humidity. Where cooler climates currently prevent the further spread of the virus, this is expected to change in future
- Leishmaniasis – This is the only tropical disease that has been endemic to southern Europe for decades, and studies indicate that the disease is emerging. Its spreading is strongly influenced by temperature and humidity
- Crimean-Congo Hemorrhagic Fever – It has been suggested that the optimum conditions for this disease are increasingly fulfilled in the EMME region through the influence of climate change on the vegetation structure

Climate change is not solely responsible for the increasing potential for vector-borne infectious diseases in the EMME, but rather it is a co-factor with several other aspects such as changes in land-use, agricultural policy and socioeconomic factors.

A recent upsurge of vector-borne diseases has occurred



## Land ecosystems and agriculture

### Impacts on agriculture

Climate conditions in the EMME allow for a large variety of crops and fruit to be grown, but some countries are already almost entirely dependent on irrigation. Overall, the future effects of climate change on crop production are expected to be negative, at least for the major crops grown in the EMME. This could have important consequences for countries with economies that are dependent on agricultural production and where the adaptive capacity is limited.

- Increasing growing seasons – Climate change can affect agriculture directly through the meteorological conditions that influence crop growth and yield. By the mid-21<sup>st</sup> Century the length of the EMME growing season may increase by about one month per year in the northern EMME
- Increasing very hot days – Most importantly for crop cultivation, the occurrence of very hot days will increase by two to four weeks per year by mid-century, which could seriously damage even high-temperature tolerant crops grown in the region

- Increasing heavy rain – Heavy precipitation events will increase by several days per year in the northern part of EMME and decrease in southern parts. Further, the increase of evapotranspiration and the decrease of soil moisture in dry areas will substantially reduce the land suitability for some major crops in the EMME

### Decreasing terrestrial biodiversity

The Mediterranean region of the EMME is among the world's highest plant biodiversity areas. However, the threat to biodiversity by extensive habitat conversion and limited environmental protection has reached critical proportions. The Mediterranean biodiversity is expected to suffer the greatest decrease as a result of climate change. In the EMME the vegetation currently at the rim of its natural distribution is expected to be most sensitive. The increased frequency, intensity and duration of extreme climate events may critically disrupt the balance between pathogens and vegetation.

# The Mediterranean Sea: Changes to marine ecosystems

The Mediterranean Sea is sensitive to environmental change and research has clearly demonstrated signs of climate-driven change. Marine biodiversity in the Eastern Mediterranean Sea is thought to be particularly susceptible to this, with impacts predicted to become exasperated even within the next 10 years.

## Changing circulation patterns

An observed abrupt change in the Eastern Mediterranean Sea circulation during the 1990s is attributed to increased salt content from less rain, reduced outflow, less river runoff, cooling from severe winters and changes in wind stress. The change in circulation patterns from these climatic drivers had a major impact on the marine ecosystems, which corroborates their sensitivity to climate change.

## Changing biological characteristics

Oxygen utilisation rates in the bottom and intermediate waters of the Eastern Mediterranean basin increased twofold following the change to circulation patterns, probably due to greater availability of dissolved organic carbon at these depths. Mesozooplankton biomass nearly doubled and species previously found only in the northernmost margins of the Mediterranean Sea suddenly became abundant.

## Increasing sea levels

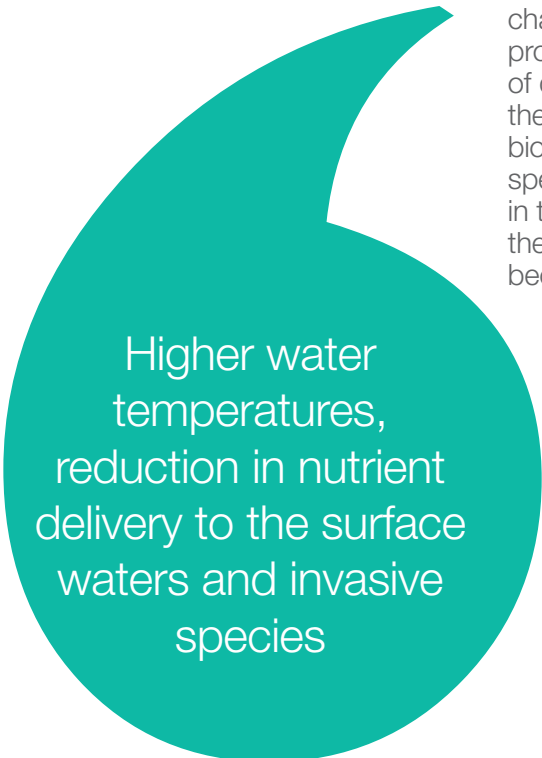
The warming of the western and eastern Mediterranean Sea will continue to dominate throughout the 21<sup>st</sup> Century with a sea surface temperature increase of 2.5-3°C expected by the end of this century. Warming of both the Mediterranean Sea's surface and deep waters is likely to be accompanied by increases in salt content as well as a sea level change of about 1.3-2.5 cm per decade.

## Marine ecosystems become more 'tropical'

Climate-driven change in water temperature, circulation patterns and sea level are anticipated to significantly affect ecosystem function in the Mediterranean Sea over the next century. Higher water temperatures, reduction in nutrient delivery to the surface waters and overall warming of the Mediterranean Sea ecosystems will be the first signs of this change.

## Increases in invasive species

There will also be movement of alien species from outside the Mediterranean Sea ecosystems as circulation changes and temperatures rise, such as invasive marine organisms travelling through the Suez Canal from the Red Sea. Increasing water temperatures will support the continued invasion of warm water species from the eastern to western basins.



Higher water temperatures, reduction in nutrient delivery to the surface waters and invasive species



## Changes to freshwater resources

There is little doubt that climate change is associated with a drying of subtropical regions, which includes the Mediterranean and the Middle East. Countries in the EMME region are already notorious for water scarcity, and the demands on these limited water resources from population growth and economic development are increasing. The predicted climate-driven changes of warmer temperatures and reduced precipitation are expected to add to the existing concerns about water availability.

### Decreasing river basin discharges

The mean annual precipitation in the EMME will probably decline between 10-50% during the 21<sup>st</sup> Century, although this decline is not uniform across the region and some countries in the south will have small increases in rainfall levels. As a result, it is predicted that the average annual river discharge of the Euphrates, Tigris and Jordan Rivers could decline by between 10-22% by the mid-21<sup>st</sup> Century, with continued declines into the latter part of the century. Such significant precipitation and water resource decreases will require

important economic and social adjustment across the region.

### Rising water shortages

Some of the EMME countries already suffer from water scarcity. Population projections combined with the predicted internal water resource availability suggest that by the mid-21<sup>st</sup> Century, water shortages will worsen in all countries which are currently water scarce. Such changes will necessitate major adaptation in the agricultural sectors of countries, which currently account for a high percentage of water use.

### Increasing desalination

Extensive desalination is considered to be required to meet even the most basic water needs of EMME countries in the 21<sup>st</sup> Century, albeit the potentially costly nature of this solution. Although the climate change effects on water resources will be significant, they are potentially manageable, although some countries with comparatively weak economies may struggle with the costs of providing fresh water through desalination.



# Energy demand

Changes in energy consumption can be linked to the changes in air temperatures and energy demand is closely connected to both extreme hot and cold weather. Considering the expected temperature increases across the EMME region, increases in energy demand as a result of climate change are very likely to occur.

## Increasing demand for air conditioning

Fairly dramatic increases are predicted in the number of days that air conditioning will be required in order to provide comfortable living conditions. By the end of the 21<sup>st</sup> Century, along most of the northern Mediterranean coast an additional 2-3 weeks per year – and further inland, up to 5 more weeks – of intense air cooling will be needed. In North Africa it is expected that more than one additional month per year of heavy air cooling will be required. These findings underscore the relatively major impact climate change will have on energy demand.

## Decreasing demand for heating

Heating requirements in the EMME will also change, especially in winter and to a lesser degree in spring.

The decrease is most evident in the northern continental parts of the region. Given the high temperature conditions in the southern EMME, the heating requirements are minor. Nevertheless, small decreases in the winter temperature are projected in North Africa and the Middle East, whereas during other seasons the changes are insignificant.

## Impacts on energy production

The additional energy demand during the future warm and dry summers happens to coincide with a deficit in water supply, which also reduces energy production by hydroelectric plants in the northern EMME. In addition, these conditions will occur at the same time as a growing demand for desalinated water. In EMME countries with limited resources, there is expected to be an increasing disparity in power supply, and a growing need for innovative solutions such as the co-generation of electricity and desalinated seawater by using solar power. Even though changes in demand for heating will to some degree compensate in terms of energy use, they are unlikely to help solve the growing problems with energy supply.





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