Ministry of Environmental Protection

## State of Israel

## Ministry of Environmental Protection

## Office of the Chief Scientist

# Israel's Preparations for Global Climatic Changes

**Phase I – The implications of climate changes on Israel, and interim recommendations**

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# Vulnerability and Adaptation to Climate Change

## Introduction

It is widely recognized that adaptation to the adverse effects of climate change is vital in order to reduce the impacts of climate change. In 2007, the UN Convention on Climate Change, held in Bali, produced an Action Plan which identified adaptation as one of the key building blocks required to strengthen future response to climate change. At the December 2009 Copenhagen Conference, the importance of adaptation was again emphasized, especially the establishment of comprehensive adaptation tools.

In Israel, the preparation of a vulnerability assessment to climate change and an adaptation plan to confront potential risks and opportunities is of vital importance due to its lack of adequate water resources and semi-arid climate. To address the challenges of climate change adaptation, the Ministry of Environmental Protection set up an interministerial steering committee in 2006, headed by its Chief Scientist, to check the potential impacts of climate change on Israel. The objective of the committee was to recommend ways of preparing and adapting to climate change in a way that would reduce potential damages, on the one hand, and promote the development of new concepts and technologies to address the problems, on the other hand.

With the aid of working groups, made up of experts in different disciplines, a draft document was presented for comments during a workshop held in the beginning of 2008. By the summer of 2008, the results of the two year process were evident in the form of an initial though comprehensive report which addresses the anticipated impacts of climate change on Israel and presents interim recommendations on adaptation measures in each of the following sectors: water, drainage, agriculture, seas and coasts, urban environment, public health, biodiversity, energy and the economy. Plans now call for these interim recommendations to be developed into a national plan on climate change adaptation.

### Past Changes in Climate in Israel and in the Middle East

Nearly 5% of the land areas in the world are characterized by a Mediterranean climate, which is distinguished by rain during the winter and a lack of precipitation during the summer (in the northern hemisphere).

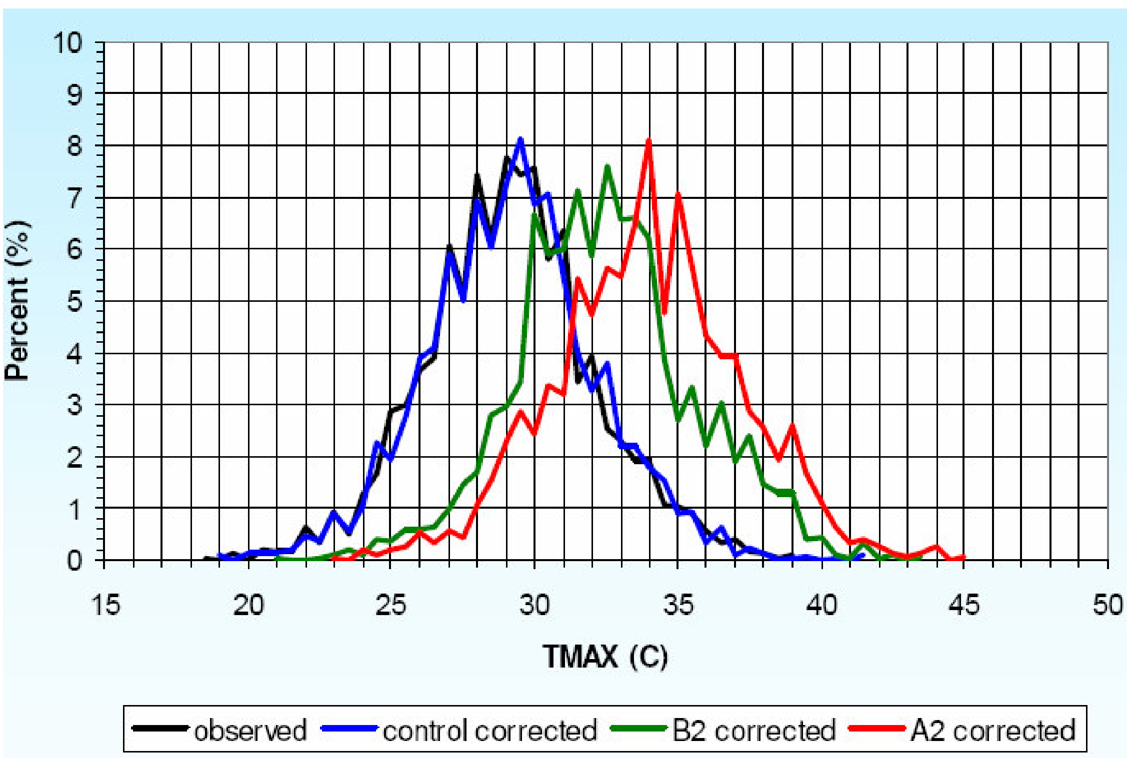
Climate in the Middle East has varied considerably over the past hundreds and thousands of years. For example, some 20,000 years ago, the average temperature was 8°C lower than today's temperature, and 6,000 years ago, the temperature was 1-3°C higher than today’s temperature. Similarly, research studies point to changes in precipitation over the last 10,000 years. For example, southern Israel encountered variations of 15% to 40% of the current average rainfall with major differences in the fauna and the flora in the different periods and changes of tens of meters in sea level.

The historical high correlation between human settlement and climate change attests to the sensitivity of systems in this area to climate change. However, it is still unclear how and to what extent human and natural systems would tolerate rapid climate change in this region.

## Expected Climate Changes in Israel

According to the A1B scenario of the Intergovernmental Panel on Climate Change (IPCC), the maximum temperature in Israel is expected to rise by 1.8° C by 2020 compared to the years 1960-1990, whereas the average temperature is expected to increase by 1.5° C. According to IPCC scenarios A2 and B2, average temperature is expected to increase by 5° C and 3.5° C in the years 2071-2100, respectively, compared to the years 1961-1990. In addition, a 10% decrease in precipitation is expected by 2020, reaching a 20% decrease by 2050.

**Figure 1: Projected Changes in Maximum Temperature Distribution***




** Refers to Mt. Cana'an according to A2 and B2 IPCC scenarios.*

Source: Alpert et al. 2007

Another expected impact is an increase in the number of extreme events in Israel, along with a decrease in the amounts of seasonal rain. According to the B2 scenario, extreme rainy days are expected to be concentrated in autumn and early winter, while according to the A2 scenario, extreme rainy days are expected to be concentrated in January and in the spring. The differences in average precipitation from year to year are expected to increase compared to today, with increases in very rainy years compared to years of extreme drought. Furthermore, the intervals between dry spells and wet spells are also expected to increase. This indicates a tendency towards a more arid climate in Israel, which conforms to the IPCC forecasts for 2100.

### Vulnerable Sectors

Climate change is expected to impact several sectors in Israel, as will be discussed in further detail in the following paragraphs. Among the major potential impacts:

- Reduced precipitation
- Increased water demand (due to warming and increased evaporation)
- Increased frequency of extreme events (heat or cold, floods)
- Changes in crop yields
- Increase in agricultural pests, plant diseases and weeds.
- Risk of damage to coastal infrastructures due to rising sea levels.
- Morbidity and mortality due to heat waves and new vectors of disease and increased risk of food-borne infectious diseases due to elevated temperatures.
- Increased energy demand (air conditioning, desalination)
- Changes in biodiversity, especially in the Mediterranean sea (jellyfish, reduction in commercial fisheries)
- Increased risk of forest fires

## Water Resources

The hydrological system impacts on and is impacted by climatic conditions. Temperature changes affect the rates of evapotranspiration, cloud characteristics, ground humidity, storm intensity, snowfall, and snow melting in different areas. Changes in precipitation affect the timing and intensity of droughts and floods, surface runoff regimes, and recharge rates of water reservoirs. In addition, patterns of vegetation and ground humidity also have an impact. An increase of 1-2°C and a decrease of 10% in precipitation, for instance, could lead to a decrease of 40-70% in the annual average flow of rivers, which will impact agriculture, water and energy supply.

Israel's water potential, based on a 36 year multi-annual average, is estimated at some 1555 million cubic meters per year (MCM). Excluding the eastern mountain aquifer, the Negev and the Arava desert, the water potential is estimated at some 1400 MCM per year. However, according to Israel's Water Authority, high fluctuations are evident between the years, with a standard deviation of 477 MCM. Out of the total, some 650 MCM of water per year are from the Sea of Galilee (the only natural freshwater lake in Israel and a primary source of water), 110 MCM per year from the Western Galilee, 130 MCM per year from the eastern basins, 320 MCM per year from the mountain aquifer, 25 MCM per year from the Carmel coast, 250 MCM per year from the coastal aquifer, and 60 MCM per year from the Negev and Arava desert basins. Nearly 60% of all water resources is allocated to the agricultural sector (although more than half is non-potable water including effluents and marginal water), more than 35% to the domestic sector, and more than 5% to the industrial sector.

In the wake of five consecutive years of drought which have significantly reduced Israel's freshwater reserves and in preparation for future climate changes, Israel has decided to include climate change within the framework of its strategic program for the water sector.

Israel's adaptation report points to the following potential impacts of climate change on water in Israel:

- Increase in the frequency and severity of floods, which may cause major damage to property and to people.
- Reduction of 25% in water availability in 2070-2099 in comparison to 1961-1990.
- Reduction in groundwater recharge.
- Loss of 16.3 million cubic meters of water for each kilometer along the coastal plain, as a result of a potential rise in sea level of 50 centimeters.
- Changes in the salinity level of the Sea of Galilee.

<u>Groundwater</u>

In general, a decrease in precipitation volume as a result of climate change will lead to decreased recharge, but estimates of the amount of rainfall reaching groundwater are difficult to obtain. Infiltration from the upper soil layer into groundwater depends on evaporation and water consumption by plants and humans, before filtration into the ground. The impacts of climate change could bring about changes in the diversity of plants that cover the ground, consequently leading to changes in enrichment capacity. An increase in extreme events, which will lead to high amounts of precipitation in short time periods, will lead to increased flooding and erosion and to decreased filtration. However, all components affecting groundwater enrichment should be assessed, and not only the change in the quantity or distribution of precipitation.

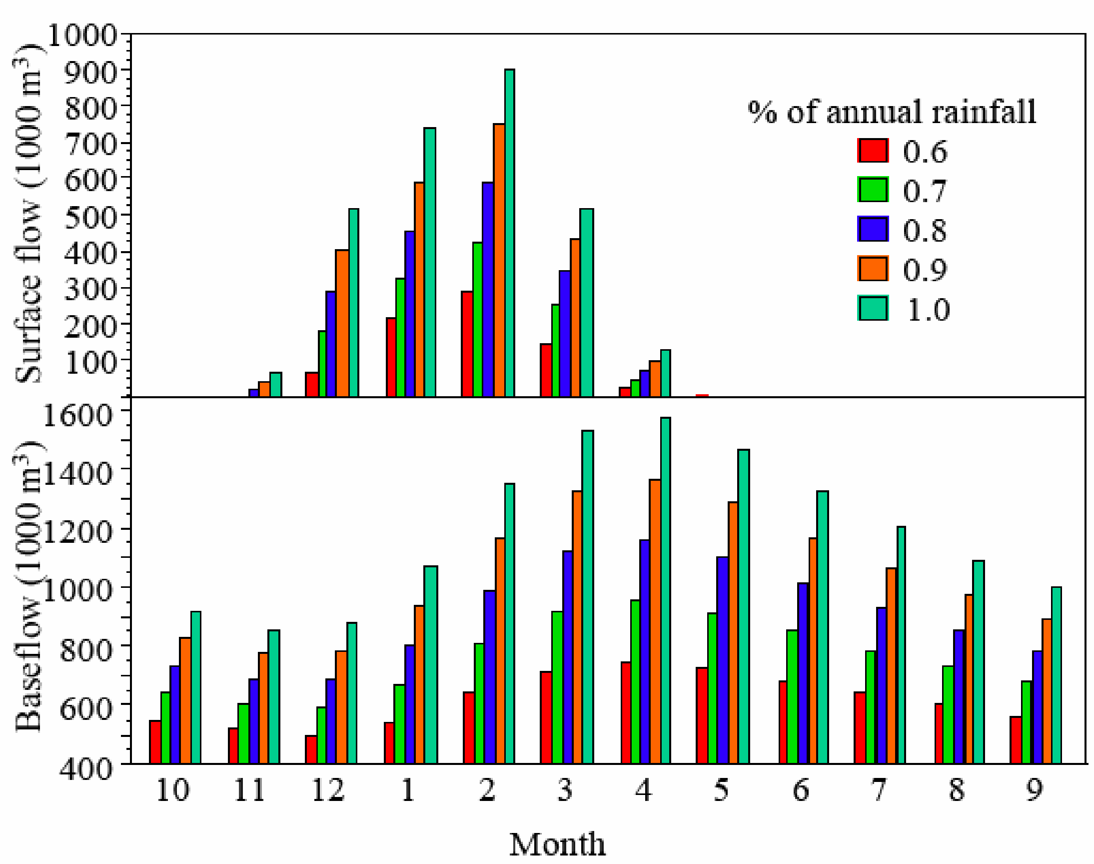
**The coastal aquifer** – The increase in population and urbanization along the coastal plain reduces water penetration into the ground and increases surface runoff. An increase in rain intensity could lead to a further reduction in the enrichment capacity of this aquifer and to a decrease in its water quality, although water could infiltrate in other areas. Additional damage to the coastal aquifer is expected due to the potential rise in Mediterranean Sea level.

**The mountain aquifer** – Flood waves are created every year in the basins of the streams which feed the mountain aquifer. A number of reservoirs have been constructed in order to capture and utilize this floodwater. An increase in rain intensity is expected to increase the flood waves, beyond the capture and utilization capacity of these reservoirs. While this water could benefit the streams as ecosystems, it will be lost to the water economy. In addition, reduced precipitation will lead to lower enrichment of this aquifer as well.

Surface water

**Sea of Galilee (Lake Kinneret)** - An increase in rain intensity could lead to increased quantities of water entering the Sea of Galilee. Changes in precipitation distribution and increased evaporation will lead to a different spatial distribution of runoff water in the winter, and will impact the recharge of the groundwater and the spring flows, which refill the different water reservoirs. These will affect water availability in the upper basin of the Jordan River and the salinity of the Sea of Galilee. According to one scenario, which investigated the implications of a 20% decrease in precipitation and a 20% increase in evaporation in the upper Jordan River basin area, a reduction of 110 MCM per year is expected, nearly 43% of the annual recharge of the major springs of the Jordan River. Another study, which checked monthly flows in the Jordan River under changing annual precipitation rates above Mount Hermon, also found a more pronounced decrease in the percentage of surface flows compared to the reduction in precipitation.

**<u>Figure 2 Average Base and Surface Flows in the Jordan Basin</u>***




** Calculated by the HYMKE model for five scenarios of rainfall reduction, in percentages (60, 70, 80, 90, and 100), compared to current conditions.*

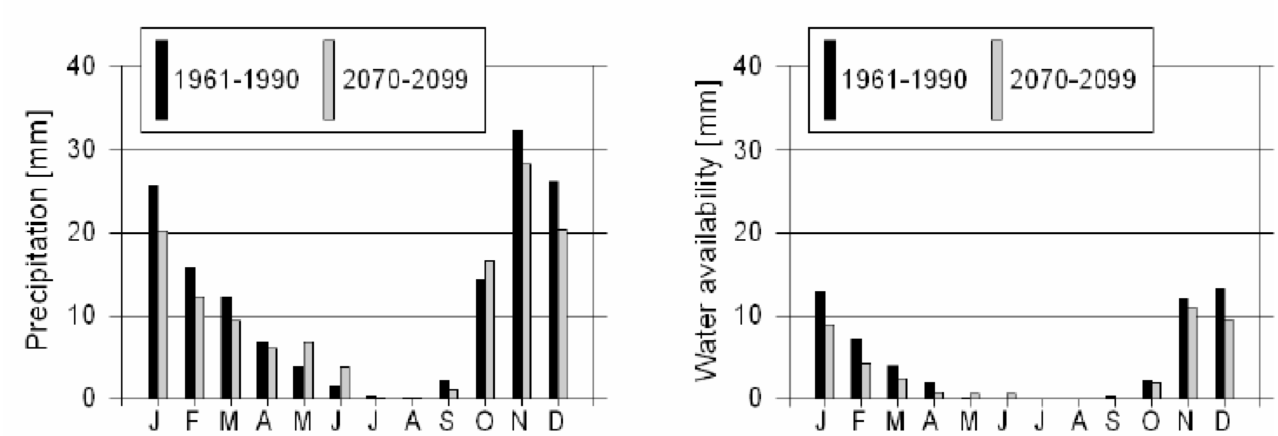
Source: Rimmer 2008.

The Kinneret Limnological Laboratory has investigated the effect of continued decreases in available water for the Sea of Galilee on the future salinity of the lake. It was found that a continued linear decrease at the current rate of water flushing the Sea of Galilee will increase its salinity up to 470 mg of chlorine by 2040.

Within the framework of the GLOWA-Jordan River project, initial estimates of the availability of water resources in the semi-arid area of the Jordan River were carried out for the years 2070-2099, compared to the years 1961-1990, according to the IPCC B2 scenario. This area spans 90,000 kilometers, from the north Jordan basin to the Gulf of Aqaba in the south, and from the Mediterranean Sea coast to the Jordan plain. According to the aforementioned study, a decrease of 11% is expected in the overall average precipitation in the area (the average seasonal precipitations are expected to decrease from 141 mm during 1961-1990 to 125 mm in 2070-2099), bringing about a 25% decrease in water availability in the coming decades, and even more in some areas.

In the Negev area, water shortage already exists under current climatic conditions, and therefore, the continued decrease in precipitation is not expected to worsen water availability in this area. However, in the northern area and in the coastal plain, a decrease in precipitation is expected to reduce water availability. Extended extreme drought conditions may endanger the very livelihood of wooden plants and various mammals feeding on them.

**Figure 3 - Total average monthly precipitation amounts and monthly water availability in the Jordan basin in 2070-2099***




** According to the IPCC B2 scenario, compared to the years 1961-1990.*
Source: Menzel et al. 2007

**Floods** - The increased incidence of major flood events, observed in recent years, which may be attributed to global warming, burdens natural and human drainage systems. Large floods cause severe damages to the ecological environment, to property, to the economy, and to human life. In a cost-benefit analysis for floods in the Ayalon basin (estimates relating to 1987 prices), damages for rain events at a probability of 1 in 50 years were estimated at 89 million NIS, and for rain events at a probability of 1 in 100 years, at 338 million NIS. The direct damage from the floods of the severe winter of 1991/2 was estimated at over 200 million NIS. In addition, indirect damages were caused due to road blockages, loss of work days, and loss of income, estimated at tens of millions of NIS. A trend of more extreme rain events and greater severity of extreme precipitation events will lead to the increased frequency and severity of floods and concomitantly to severe damages to property and humans. The benefits from minimizing these damages include prevention of ecological hazards such as enhanced risk of extinction of wildlife and plants, prevention of agricultural produce loss, prevention of damages to private and public property (public structures, roads), prevention of disruptions to economic activities and loss of income to individuals and the economy as a whole, prevention of damage to and loss of human lives, improvement in the quality and quantity of national water resources, and improvement of national soil resources.

In summary, for the Mediterranean region, the increase in temperature is less significant than the expected changes in precipitation, in evapotranspiration, in surface runoff and in ground humidity, which are critical factors for the management and planning of the water economy. Decreased precipitation, especially in countries in which the exploitation of water sources is extensive, such as Israel, may lead to national water crises, with a continued decrease in the levels of water reservoirs, basins, and rivers. Population growth and recently occurring droughts place water sources under pressure, and require novel approaches for the planning and management of the water economy, in order to avoid conflict and environmental damage

## Agriculture

The economic value of agriculture in Israel is comprised of 25 billion NIS per year for agricultural produce, $1.2 billion for agricultural products for export, and $0.9 billion for processed food. The total area cultivated for agriculture is 4,300 square kilometers.

In addition to agricultural output, agriculture is also a public commodity which provides external benefits such as preservation of open space in the rural and urban environment, scenic views, diverse and unique landscapes, contribution to tourism, pollutant absorption, and contribution to air quality. Nearly 40% of Israel's agriculture has landscape value, which is highly rated, due to the density of population and the lack of green areas in the natural landscape. Therefore, damage to agriculture, beyond damaging certain crops, also has an adverse impact on green areas, tourism and more.

The indirect economic benefits which Israeli agriculture provides were estimated at 1.3 billion NIS per year (2002 prices). This value incorporates different aspects. A savings of $50 million a year is estimated through the utilization of effluents in agriculture, at a quality lower than that required for discharge to natural streams. The absorption of approximately 2 million tons of $CO_2$ per year has been estimated at about $20 million per year, due to the possibility of emissions trading. The extent of agro-tourism has been estimated at approximately 75 million NIS per year, which is expected to increase with the growth in population and incoming tourism.

Agriculture also serves as an open area for the development and conservation of wildlife and for rainwater infiltration to groundwater. Hence, the social-environmental contribution of agriculture goes beyond its business contribution.

Israel's adaptation report points to the following potential impacts of climate change on agriculture in Israel:

- Damage to crops due to a reduction in water availability in the soil, 20% increase in water demand for irrigation, reduction in fruit and vegetable yields, emergence of new pests and pathogens and increase in the frequency of animal and plant diseases.
- Sharp cutbacks in allocations of freshwater resources for agricultural irrigation.
- Possible advantages to growth due to an increase in $CO_2$ concentrations in the atmosphere, but potentially also leading to reduced crop yields and intensified use of herbicides.
- Increased risk of soil erosion.
- Higher winter temperatures will benefit certain crops.
- Reduced productivity of farm animals.
- Shortage of animal feed and increase in its cost.
- Shortening of the productivity season of pastureland.
- Damage to populations of pollinating insect species.
- Damage to the nutritional value and shelf life of agriculture produce.

In recognition of the potentially severe impacts of climate change on agriculture in Israel, the Chief Scientist's Office of the Ministry of Agriculture and Rural Development has issued a call for proposals on research studies on the subject in September 2009. The aim is to generate the necessary information for the purpose of developing tools for confronting and adapting to future climate changes.

**Implications of climate changes on agriculture** - Israeli agriculture is particularly vulnerable to climate change, due to the proximity to the aridity line, the relatively low amount of cultivated areas, and the steep gradient from north to south and from west to east along the country. Possible climate changes expected to impact agriculture include: change in precipitation amounts, change in temperature trends, ecological changes and increased concentrations of $CO_2$. Severe damage to agriculture is expected primarily as a result of the potential increase in extreme weather events, rather than as a result of changes in the annual average.

**Implication of changes in precipitation** - An increase in extreme rain events will lead to an increase in surface runoff, increased transport of pollutants to surface water bodies, increased infiltration of pollutants into groundwater and damage to crops. An increase in extreme rain events will also increase the risk of soil erosion, whereas, approximately 40% of field crop areas and agricultural lands, and 10% of fruit grove areas are classified in the category of severe erosion.

Decreased amounts of precipitation will lead to decreased infiltration and decreased availability of water in the ground for summer and winter crops. In the wake of a decrease in precipitation, the rainy season may shorten, requiring earlier irrigation of summer crops, as well as extensive irrigation, as a result of inadequate flushing of salts from the soil profile during the winter. In addition, farmers growing rain dependent crops are currently unprepared for drier conditions. Since water demand will increase with the expected decrease in precipitation, dramatic cuts in the allocation of natural water sources to agriculture are expected in coming years, with the possibility of a complete ban on freshwater supply to agriculture during periods of prolonged droughts.

Studies have demonstrated the ways in which the expected decrease in precipitation in Israel will lead to economic damages in the agriculture sector. One study examined the influence of two climatic scenarios (A2 and B2) for the years 2070-2100 on wheat, a central crop in the southern region of Israel, and cotton, which represents the more humid north. For wheat, under the A2 scenario, the profit turned negative (between -145% and -273% relative to current values), and under the B2 scenario (more moderate), a mixed trend was obtained (between -43% and +35% relative to current values), probably due to an increase of 17% and 10% in precipitation amounts in January and March, respectively, under this scenario. This demonstrates that even under the moderate B2 scenario, a change in the distribution of precipitation during the growth period significantly affects the expected crops. For cotton, on the other hand, under both scenarios, a significant decrease in crops was found, leading to significant economic losses (-240% under the A2 scenario and -173% under the B2 scenario, relative to current values), and an increase of 25% in water consumption. It was found that farmers could compensate for the water loss by nitrogen fertilization and additional irrigation, in the case of the moderate scenario, but not by changing the dates of seeding. Therefore it is anticipated that crops which are currently rain-dependent will become irrigation-dependent in the future, due to the expected decrease in water supply in the area.

Another research study examined three damage scenarios to agriculture as a result of a possible 4% reduction in precipitation. According to the first scenario, an arbitrary cut in the production of all crop groups will lead to an annual loss of approximately $208 million (2000 prices). According to the second scenario, which included partial preparedness by the agricultural sector, the expected annual loss will be $101.5 million (2000 prices), including some $40 million from indirect cuts in water for irrigation. A third scenario took into account expanded use of desalination for the supply of potable water for household consumption. The annual cost of this scenario is approximately $126 million (2000 prices, cost assumed at 80 cents per cm of desalinated water).

It should be noted that these two studies did not examine adaptation actions, such as technological improvements, crop improvements, agro-technical changes (such as crop rotation), and the effect of increases in $CO_2$ concentrations and other atmospheric changes on crops.

**Implications of changes in temperatures** -The implications of an increase or a decrease in temperatures depend on the intensity, frequency and duration of the heat or cold periods. A number of positive impacts are expected from temperature increases, due to the fact that farmers adapt their crops to the climatic conditions in the area. This adaptation is largely accomplished by utilization of the heat conditions. Thus, Israeli agriculture is relatively tolerant to heat conditions. In Israel, especially in warmer areas, fruit, vegetables and flowers are grown during the winter, and are primarily exported to Europe. This allows Israeli products to reach the market early, and to sell for high prices in the European and local markets. In this case, higher temperatures have an advantage by overcoming water scarcity while using irrigation.

Another benefit to crop yields, in the wake of temperature changes, is expected from the change in seeding and blooming times of the crops. This change could prolong the growth season.

One research study examined the economic implications of the adaptation of Israeli agriculture, excluding farm animals, to increased temperatures. The study used a model which takes into account adaptation activities which farmers could take, such as crop rotation, changes of crop types, and technological techniques. When irrigation quotas were dictated to farmers, a slight increase in temperature (forecast for the year 2020) led to increased profits, but the continued increase in temperatures (expected by 2100) led to decreased profits. Without limits on the irrigation quotas, the temperature increase led to profit increases over time. Thus, additional irrigation helped to reduce the effects of the temperature. Nonetheless, it should be taken into account that the research assumption was that water supply will not change with climate change.

A potential damage to agriculture, due to temperature change, is reduced productivity of farm animals. Animals on an agricultural farm (chickens, cattle, sheep) are very sensitive to heat, since they are of European genetic descent, which is more suited to a cold climate than to the Middle Eastern climate. Therefore, their suitability and ability to produce high quality yields, under Israel's heat conditions, is problematic. Nonetheless, Israel has been coping with the constraints of climate for many years, by such means as improved living conditions for the animals, use of better structures, air conditioning systems, and others. Hence, it is assumed that this sector will almost not be directly affected by climate change, in terms of expected increased temperatures and humidity in this region. Nonetheless, the need for heating or cooling of the livestock sheds (and greenhouses) is expected to increase. In addition, one of the main consequences of climate change on farm animals is on their food (animal feed) since 30% of the cow feed on Israeli farms grows in Israel and is based on rain water. A series of arid years, or an extreme arid year, could lead to shortage of animal feed.

**Implications of ecological changes** - Ecological changes, expected in the wake of climate change, include risks of wood drying or fires in dry habitats, and shortening of the production season of grazing areas, thus damaging the animal feed.

Also, in recent years, an increase has been observed in farm animal diseases, which originate from mosquitoes and pests. This increase could be caused by a number of factors, including climate change (i.e., rise in temperature, which leads to an increased rate of pathogen growth). The increase of nocturnal summer temperatures, observed in recent years, contributes to maintaining high temperatures during most hours of the day, which enables a more rapid growth of disease vectors. In addition, a northbound migration of insect populations has been observed, with southern insect populations overtaking the habitats. In extreme weather areas, such as the Arava desert, a small change in climatic conditions is significant for insects, and could lead to the deterioration of certain insect species, which have managed to survive to date. In areas with a moderate climate, a small change is not expected to lead to the deterioration of these populations.

**Economic implications of climate changes** -There are a number of economic considerations which accompany the implications of climate change on agriculture:

- A rise in the incidence, intensity and frequency of extreme weather events will damage crops and will cause severe economic damages. For instance, in 2008, the damage from a freeze wave was estimated at more than 500 million NIS.
- The expected decrease in water availability in the area will lead to heavy economic damages to agriculture. About 60% of the water supply is diverted to irrigation, and water supply is heavily controlled via consumption quotas. Nearly all crops are irrigated, except field crops. In 2006, freshwater contributed only 47% of the water allocated for agricultural use, and its relative part in agriculture continues to lessen with the years. Nonetheless, there are sectors which consume mostly freshwater, such as orchards, vegetables, flowers, and the cattle sector. A cut of 50% or more in freshwater quantities for agriculture is very realistic according to the climatic scenarios expected in Israel, and the economic damage is estimated at billions of NIS. Reducing agricultural water consumption by 200 MCM per year, as expected according to several forecasts for 2020, will lead to reduced income of approximately $100 million a year and a loss of thousands of jobs.
- A decrease in the feed quality for livestock and an increase in its prices will lead to reduced profits. The shortening of the production season of grazing areas will lead to increased usage of more expensive feed substitutes. For instance, grazing lands in humid Mediterranean climate areas currently save cattle growers $83.2 per hectare a year and $116.5 per hectare a year for sheep growers.

- A loss of soil, due to erosion, is estimated at some 15 NIS per cubic meter. In the case of 100,000 hectares, which are a million cubic meters of land, the value adds up to 15 million NIS.

## Coastal Zone -The Mediterranean Sea

Israel has been monitoring the Mediterranean Sea level since 1992. For that purpose, the Israel Oceanographic and Limnological Research (IOLR), a national research institution, was established with the mission of generating knowledge for sustainable use and protection of Israel's marine, coastal and freshwater resources.

Research studies have shown that in the Eastern Mediterranean area, sea level is expected to rise by 0.5-1 meter by 2100. Sea level in the Israeli coast is expected to rise by some 0.5 meter by 2050 and by approximately a meter by the year 2100. While some researchers claim that increased evaporation, due to the temperature increase, could be a moderating factor on the rise of sea level, others claim that this conclusion is unfounded.

An increase in the height and intensity of waves which penetrate inland, due to the increased intensity of extreme weather events, will increase the penetration of sea water inland in lower areas, and will cause damages to water sources in the area and to coastal natural resources.

Israel's adaptation report points to the following potential impacts of climate change on Israel's Mediterranean coast:

- A 10 cm rise will lead to a 2-10 meter retreat of the coastline and to the loss of 0.4-2 square kilometers of coast every 10 years.
- Retreat of the coastal cliff and expansion of the risk zone of the infrastructure constructed on the coastal cliff by 40-50 meters eastward.
- Damage to coral colonies in the Gulf of Elat.
- Damage to coastal tourism and recreation.
- Damage to coastal structures (e.g., jetties and marinas, intake points of cooling seawater for coastal power plants) and to archeological sites.
- Damage to species and ecosystems of the coastal environment.
- Increased water temperature in the Mediterranean Sea will lead to increased penetration and increased establishment of alien species originating in the Red Sea/Indian Ocean.

**Implications of the rise in Mediterranean Sea level**

A rise in Mediterranean Sea level may have many implications, but there is no model today which accurately presents the anticipated and possible implications on the coastline, aquifers, archeological sites, habitats, and others.

Nonetheless, several consequences in case of sea level rise are expected. A 10 cm increase in sea level (assuming a slope of 1-5% in the Israeli coast) will lead to a coastal retreat of 2-10 meters, which will lead to a loss of 0.4-2 square kilometers every 10 years. A one meter increase in sea level will flood a 50-100 meter wide belt on sandy beaches, which constitutes more than half the length of the Israeli coastline. One estimate, based on a scenario in which such an increase will take place until the year 2060, predicts that 8.4 square kilometers of beaches will be lost, with an economic damage of 4-5 billion NIS. A one meter rise will also increase the extent of the rocky beach bays and will shift the storm line an average of some 100 meters eastward (inland) on sandy beaches. In other beaches, the coastline will migrate tens of meters and, in certain places, could shift by over 100 meters, depending on the level of rise, the strength of the sandstone (kurkar) ridges and cliffs along the coast, and the change of the wave regime and frequency of strong storms. Migration of the coastline eastward will also lead to the infiltration of sea water to river deltas.

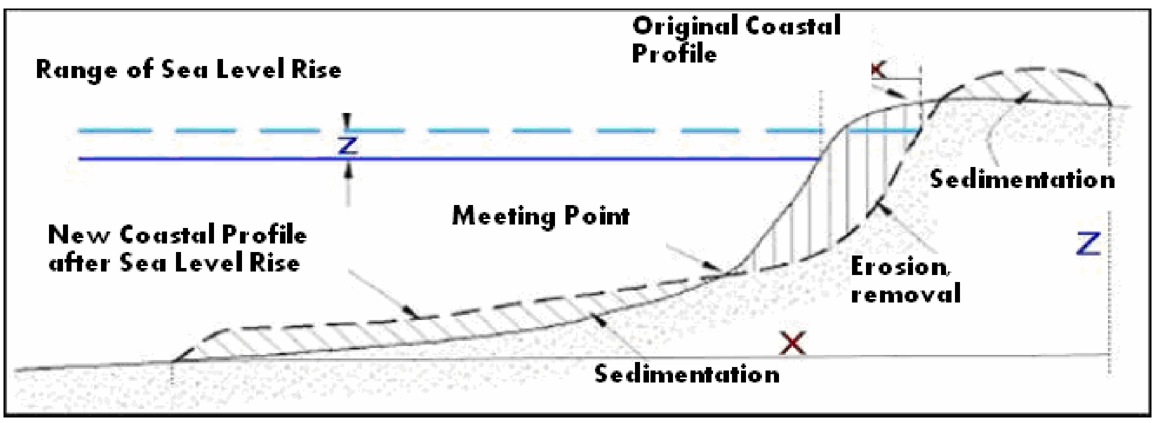
Migration of the coastline is affected not only by changes in sea level, but also by the height of the land, the relations between land and sea level and the sand balance, which is affected in populated beaches by human intervention in these processes (e.g., construction, sand mining, digging from the coastal strip and sea bed and the artificial transport of sand on land and in the sea).

Sea level rise will lead to the increased retreat of the delta beaches and to an increase in the amount of sand which is transported to the beaches of Israel, assuming that the wind and wave regimes will not change significantly in terms of flow directions. Due to the relative location of the Israeli coast in the Mediterranean Sea, the direction of the highest waves, which is generally westerly, is not expected to change. However, if wind frequency and intensity will change, a multi-annual change in the quantities of the transported sediments could occur, and perhaps even in the net direction of the transport, on a multi-annual average. Under such conditions, it is hypothetically possible that the sand transport balance will shift along the coast, and coastal retreat may increase. Coastal facilities and structures, such as sewage outfalls, sewage and fuel pipes, docks, marinas, harbors, breakwaters, and others, are situated along the sand transport path on the beaches. Increased sand removal from the coasts and the lack of sand on the other side of coastal structures, along with sea level rise, will also lead to the migration of the coastline eastward. At the same time, if the abrasion will be consistently larger than the sand accumulation process, the coastline will shift inland, even if sea level remains stable.

The shift of the swash zone (the border of sea and land, which is several tens of meters wide), due to the rise in sea level and the shifting of the waterline eastward, will transfer part, or most, of it beyond the range of the current coastline, to sloping areas, with a higher slope than that the current strip. In these areas, the supply of sand from the waves will decrease and the exposure of the west sandstone slopes will increase. In a steeper swash zone, waves descending into the sea will grow stronger and will carry the sand which has been deposited by the rising wave back to the sea. This phenomenon is currently observed in extremely steep beaches and is expected to widen to additional coasts.

In the wake of sea level rise, the coastal profile (the shape of the local section, perpendicular to the coastline) is expected to shift towards the coast, with an upward diversion, and the sand which will be detracted will sink in the hindpart of the coast (Figure 4).

**Figure 4 Change in coastal profile as a result of sea level rise**




Source: Rosen 2005.

Additional possible consequences of sea level rise include damage to tourism, to recreational activities on beaches, to coastal structures, docks, marinas, and archeological sites, to coastal ecosystems, and to the coastal biodiversity. Based on initial estimates, lesser impacts are expected on the coasts of the Gulf of Elat than on the Mediterranean Sea coasts, due to the different nature of the coast in terms of the profile slope and coastal structure, except for severe damage to the coral colonies, due to the warming of the water (coral bleaching).

**Implications of sea level rise on the coastal aquifer**

The depth of the coastal aquifer is approximately 150 meters along the coastline, and it shallows out to a few meters some 10 kilometers eastward from the coastline. Today, the maximal penetration of sea water inland is 1000 meters from the coastline. In areas where sea water has penetrated deeper into the aquifer as a result of over-pumping, pumping wells have become salinated and were shut down as drinking water sources, and even as irrigation sources.. In areas of over-pumping, the level of groundwater has decreased, so that depressions have been formed at a depth of 1-3 meters below sea level, mostly 1-3 kilometers from the coastline. Therefore, the penetration of the freshwater/seawater interface beyond one kilometer into the coast could cause severe damages to water sources.

According to the lithological parameters of the aquifer, the rise in sea level will primarily influence the upper layers in areas of low topography, mostly in river delta areas which flow into the sea, such as the Yarkon and Ayalon in Tel Aviv. The coastal erosion processes, due to sea level rise, could erode the less penetrable materials, so that more penetrable layers will become exposed, and the coastal aquifer will become more vulnerable to sea water penetration and erosion.

Studies suggest that the total loss of groundwater due to a possible increase of 50 cm in sea level could reach 16.3 million cubic meters per kilometer of coast. This loss will worsen if the frequency of arid years will increase, during which the recharge rate of the aquifer will not reach the annual average.

**Implications of sea level rise on the coastal cliff**

Seventy kilometers out of Israel's 190 kilometer coastline are characterized by a coastal cliff, measuring 30-40 meters in height. All cliffs, by nature, are unstable and define the landscape for short time periods. The rate of cliff retreat is determined by its general strength and the wave climate along the coast. Waves, which erode the base of the cliff, and surface runoff activity, are amongst the main processes which contribute to the collapse of cliffs. These natural processes are accelerated by human activities at the hinterland of the cliff (primarily construction and development), by sea level rise, which may occur in the wake of climate change, by the filtration of rainwater, irrigation water and sewage water, and by strong winds. Natural barriers (such as beach rocks) or artificial barriers (such as breakwaters) contribute to an early breakage of the waves, and so protect the cliff locally, and for a limited time, but have no influence on the rate of cliff retreat (except for such barriers as sea walls, which prevent contact of the seawater with the bottom of the cliffs completely). Cliff retreat occurs in a ragged, winding line, which is a combination of the local strength of the cliff (its resistance to erosion and abrasion), the local wave regime, and random events. Such retreat does not damage the cliff's morphology, and it maintains its shape as long as there is no human intervention in the natural processes. External factors constantly affect the cliff, and a change in one factor on occasion causes the collapse of the cliff and a local slide. The products of the collapse accumulate at the base of the cliff and are washed back by the waves, enabling the waves to directly strike the cliff base and create a concave cliff, which allows another collapse cycle. The strength of the waves which strike at the base of the cliff is determined by the sea level and by the intensity of the wind and its direction. Surface runoff creates channels of dozens of meters at the front of the cliff. Due to change in the natural drainage and reduced filtration, the surface runoff creates wider channels which enhance damage to the cliff.

The coastal strip is densely populated, and the collapse of the cliff in especially dense areas, such as Netanya and Ashkelon, is a special problem, since human activity on the cliff and on its hinterland additionally contributes to the weathering of the cliff. The coastal area in the center of the country has remained stable over the last 2000 years, but during the 20th century, moderate erosion began following sand mining from the beaches (until 1965), construction of coastal structures, and lack of coastal maintenance.

The expected rise in sea level and in the frequency and intensity of winter storms will cause severe damage to the coastal cliff of Israel, which will continue to recede during the current century by tens of additional meters. The cliff will continue to collapse for dozens of years, until it reaches a stable slope, even if actions to protect its base are taken. The retreat rate of the top of the cliff eastward, as measured by comparing aerial photographs from 1945 and 2004, is a few tens of centimeters per year (approximately 20 to 30 cm). Although the rate of coastal retreat is rapid on a geological scale, and even on a historical scale, it is not expected to endanger or jeopardize the residential infrastructure east of the cliff rim, if a 50-meter wide strip will be allocated east of the cliff in which construction, digging, paving and development will be prohibited. Maintaining the width of this strip will help preserve the cliff in its natural condition for at least 200 years, assuming that the present rate of retreat is maintained. Nonetheless, researchers claim that under the conservative assumption that the processes impacting on the cliff will not change in the future, the area of risk for cliff destruction until 2100 is 20-30 meters eastward from the current cliff line in 65% and 80% of the cliff length, respectively. According to this assumption, there are some areas in which tens of buildings fall within a risk area.

Migration of the water line by some 10-30 meters eastward, expected by the year 2100 (given coastal slopes of single degrees), in the wake of a one meter rise of Mediterranean Sea level, will increase the rate of cliff retreat by tens of additional meters by the year 2100, whereas the assumed risk area will be 40-50 meters east of the current cliff line.

Cliff retreat will cause extensive economic damage, including damage to existing properties and infrastructure in the proximity of the cliff, loss of valuable real estate (because of their proximity to the sea), damage to construction plans in the making, damage to high-value lands (beaches, nature reserves), destruction of archeological sites and heritage buildings, loss of coastal areas due to sea flooding, and consequently, an eastward retreat of the territorial water of Israel.

Estimates of the damages due to cliff retreat have been undertaken according to an estimate of alternative building costs for existing buildings and for properties which could be damaged. The damage to existing buildings has been estimated at between 67 and 90 million NIS, if the retreat rate is accelerated to an average of some 0.5 meters per year, reaching up to 276 million NIS if the retreat rate reaches a one meter per year average. The market value of the properties which could be damaged has been estimated at between 195 and 265 million NIS if the rate of annual retreat increases to approximately 0.5 meters per year. If retreat rates will increase to about one meter per year, the damages are estimated at 800 million NIS.

A gradual decrease in the land resources along the rim of the cliff, despite their high economic value, is inevitable, and even if their existence can be prolonged by the construction of protective walls, their value will decrease at the rate of the required investment for implementation and maintenance. The expected damage from the loss of construction potential and the loss of value due to proximity to the beach is not significant, assuming that the construction potential is realized in alternative land. The damage to archeological sites is difficult to estimate, since these are not commodities. The value of sites may be estimated by the costs required to protect them.

Some researchers expect no damage to natural reserves from the continued retreat of the cliff, on the grounds that coastal cliff retreat is a natural process and nature reserves in the cliff area enable these processes to continue. Therefore it is generally believed that protection of the cliff will damage landscape and natural values. However, this may not necessarily be true in the case of accelerated retreat as a result of sea level rise, a process which could be faster than the ability of the natural systems to adapt, as is the case with other natural processes, which may be harmed and are already harmed today by climate change. On the other hand, protection of the cliff and the absolute prevention of its retreat will also interfere with natural systems.

The economic loss due to coastal recession (diminishment of coastal areas) of some 10 meters in 20 years is estimated at 180 million NIS. On the other hand, activities to protect the coast, which will extend its area by one meter, will lead to an economic value of the same amount. The cost estimate per meter of cliff length is between 12,500 NIS to 35,000 NIS, based on the means of protection.

**Implications of water temperature increase in the Mediterranean Sea**

The increase in water temperature will increase the ability of alien species from the Red Sea to become established in the Mediterranean Sea. Species from the Red Sea, limited by the temperature range and salinity, expand the limits of their distribution in the Mediterranean Sea via the Suez Canal. The warming of the water could impact on a variety of population characteristics, such as breeding and survival ability and could establish inter-relations between species, and hence affect the dominance and frequency of alien species, which may provide alien species from the Red Sea with an advantage over the Mediterranean Sea species. One consequence of pushing out the local biota is damage to fishery, since most of the alien species are of lower nutritional value than the local species. An example of an invading species is the *Rhopilema nomadica*, a type of jellyfish, which has appeared in Israel in huge flocks every summer since the mid 1980s. The *Rhopilema nomadica* feeds on zooplankton, which is the major food source for many fish species. Consequently, inadequate quantities of food are left for the local fish species during the summer, and the fishery sector is damaged. In addition, the *Rhopilema nomadica* damages tourism and coastal infrastructures. Local authorities report a decrease in the number of tourists on the beaches, due to the risk of jellyfish stings. Also, the jellyfish block water pipes used in the cooling systems of ships and coastal power plants.

## Human Health

One of the re-emerging diseases as a result of climate change is malaria. Malaria is a parasitic (infectious) disease, endemic to over 100 countries worldwide, and transferred to humans by the bite of the female *anopheles* mosquito. There is a risk of outbreak of this disease in countries where it had been eradicated dozens of years ago, especially due to the high mobility of tourists and immigrants. Since the 1960s, Israel has been considered a malaria free country, although every year, 60-100 cases of imported malaria are reported by people who have contracted the disease overseas. Eradication of the disease has been achieved without the elimination of the disease carrying mosquito population, and today, six species of malaria carrying *anopheles* mosquitoes are found in Israel, four of them with permanent populations, concentrated in freshwater sources. Therefore, the possibility for renewed local morbidity in Israel exists, especially given the disease distribution in neighboring countries such as Turkey. Such a new outbreak of malaria will mostly damage tourism, and will require spraying of larger areas. However, it is estimated that malaria will probably not break out in Israel, despite climate change, since local conditions do not favor the spread of the disease.

Another disease which could re-emerge as a result of climate change is West Nile Fever, which is mainly transferred among fowl by mosquitoes in water rich organic matter. The virus exists in the Middle East and also in extensive areas of Africa, Asia, and Eastern and Southern Europe. The main danger for humans is an emergence of meningitis and encephalitis, especially in the elderly or in immuno-compromised patients. In Israel, the main outbreaks of the disease occurred in the 1950s and in 2000. In following years, the number of infected people decreased due to improved preparedness and management by authorities and increased public awareness.

Israel's adaptation report points to the following potential impacts of climate change on public health:

- A rise in extreme weather events along with higher temperatures may increase the mosquito population and change its distribution.
- Low probability risk of renewed outbreak of malaria.
- Higher temperatures in the beginning of the spring may bring forward mosquito and West Nile Fever hazards to humans.
- Increased heat burdens may harm the elderly, the ill and workers exposed to heat.

**Implications of climate change on public health**

A change of several degrees in temperature range will probably not affect mosquitoes, which can survive a wide temperature range, and already cope with existing temperatures in Israel. Increased temperatures in early spring (March) could lead to the appearance of West Nile Fever, due to an increase in mosquito hazards. Increased heat burdens in urban areas could also contribute to the outbreak of the disease.

In addition, following rainy years, an increase in the mosquito population and the number of incubation areas is noted. Therefore, extreme precipitation events could potentially increase their population levels and change their distribution. However, for a significant increase in the mosquito population to occur, large amounts of rain are required over a number of years.

An increase in heat loads will hurt the elderly, the sick and workers exposed to heat. However, most of the buildings in Israel are already equipped with air conditioners and therefore the expected impacts may not be significant. An increase in flood events, due to the increase in extreme rain events, will lead to an increase in injuries and deaths as a result of damages to infrastructure and buildings and could put a heavy burden on the health services.

A workshop on the impact of climate change on public health took place in Israel in December 2009, with the participation of experts from the Ministry of Environmental Protection, Israel's universities and hospitals. One of the studies presented related to the potential rise in humidity as a result of climate change, which, along with high temperature, is a major contributor to heat burden and consequent human discomfort. A study on climate and mortality in Tel Aviv based on a time series approach, which was conducted within the framework of the CIRCLE EU project, found that humidity had a greater effect on daily mortality and morbidity than temperature. While the impact of temperature and humidity in the city of Tel Aviv, where air conditioning is highly used, seems to differ from European Mediterranean cities, further research is needed to explore the effect of different climate indices on mortality and morbidity in Tel Aviv in order to institute effective public health intervention. Furthermore, it was noted that further research is necessary in order to understand the impacts of climate change on foodborne and waterborne diseases.

## Biodiversity

Biological diversity is an overall indicator for the extent of variance and diversity in the natural world. Biodiversity includes the number and diversity of animals, plants, and microorganisms, the genetic diversity within and between population species, and the existing diversity between different ecological systems in nature.

Despite Israel's limited space (22,000 $km^2$), it is home to some 2,388 species of plants, approximately 100 species of mammals, and some 450 species of birds. This wealth stems from a number of factors:

- The geographical location of Israel, which is a land bridge between the temperate climate areas of the north and desert areas, and beyond them, with the rain forest strip of Africa and Asia. This bridge allows for the passage of animals and plants from one habitat to another.
- Israel has a diversity of landscapes and climate zones, including mountainous, transverse areas, flat plain areas, and many other landscapes. These create a large diversity of ecosystems.
- The climate changes which have taken place throughout history enabled the infiltration and local adaptation of species from equatorial regions and from tempered regions in the north.

A total of 146 species of mammals, amphibians, fish and birds are in danger of extinction in Israel and about 410 plant species are endangered. About 20% of the area of Israel is allocated to nature reserves. However, the nature reserves in the north of Israel are relatively small, which makes it difficult to maintain a functioning ecosystem. Southern reserves are larger, but they face different difficulties such as intensive human activity.

Israel's adaptation report points to the following potential impacts of climate change on biodiversity:

- Spatial movement northward in the distribution of Mediterranean species and their replacement by desert ecosystems, which will migrate from the Negev.
- Appearance of blue-green algae in the Sea of Galilee, which produce toxins, and may adversely impact the quality of potable water and reduce biodiversity in the lake.

- Some species of plants and butterflies were found to be less vulnerable to the forecasted reduced precipitation. However, prolonged intra-seasonal periods of dryness will adversely impact plant life.
- Increased dry conditions and a lengthening of the dry season will increase risks of forest fires.

**Implications of climate change on biological diversity**

Israel has sensitive biological systems, vulnerable to climate changes, such as the Red Sea coral reef and ecosystems in relatively isolated locations such as Mount Hermon, Mount Meron, and the Carmel. Areas rich in species (in terms of number) respond faster to climate change than areas poor in species. The resistance of various species to potentially more severe heat and dryness conditions depends on the different species.

A rise of 1.5°C is expected to lead to a spatial shift northward of 300-500 kilometers in the distribution of Mediterranean organisms and the occupation of the area by desert ecosystems from the Negev. The desert line will move northward and Mediterranean systems, which are currently on the edge of the desert, will be transformed into desert. As a result, species that are less resilient to dryness could be pushed aside. A sequence of arid years, or a decrease in precipitation, could adversely impact the functioning of these ecosystems.

One study has found that an increase in extreme rain events benefits the vegetation in arid areas, but damages the vegetation in more humid areas, such as Mediterranean and humid Mediterranean climates.

A reduction in precipitation or changes in the distribution of precipitation will adversely impact on the infiltration of water to the soil, causing plant species which require more water to disappear, while more resilient plants will survive. The main threat is to forest areas, groves, and open areas in the semi-arid zone. The most significant effects of precipitation changes are expected in this region, which is already susceptible to impacts of climate and droughts, and whose main constraint is water availability. Nonetheless, other studies have demonstrated that a 5-25% reduction in precipitation amounts, a 1.5°C increase in the average seasonal temperature, and a 10% increase in moisture, will have minimal impact on the primary productivity in leafy vegetation in the semi-arid area, since the vegetation in this area is adapted to stress conditions and makes optimal use of the available water.

Research in the semi-arid region shows that over the last 3,000 years, fluctuations of 20% in precipitation have occurred, shifting from moist and stable conditions, with approximately 600 mm of rain, to dry conditions, with some 450 mm of rain. This fluctuation in precipitation did not cause any significant change to the environment, although it can clearly be seen in the sediment accumulation and in changes in the plant cover of the land. The characteristics of the Mediterranean vegetation during this period were similar to those of today, although during the moist period, the richness of vegetation was higher than in the dry period.

It can be concluded that there are plant species in Israel, some of them in the semi-arid zone, which have adapted to stress conditions of heat and dryness over the years, and can cope with a certain reduction in precipitation. Nonetheless, it is unclear whether these species will be able to survive an aggravation in heat and dryness conditions in the long range, due to climate change, especially an increase in dry periods, duration of heat loads, and increased frequency of drought years. Research studies have shown that a sharp decrease in precipitation in the south has already caused extensive changes in land cover and underlying biota, creating runoff and soil erosion.

Climate change also increases the likelihood of forest fires. According to Jewish National Fund data, no increase in the number of forest fires or in the extent of forest area was observed in recent years. There are years during which the combination of weather conditions, along with other factors, such as arson, lead to an increase in the number of fires. Extreme days, especially during transition periods, or the lengthening of the dry season, bear a significant effect on the likelihood of forest fires, while the increase in temperature bears a lesser effect.

The impacts of climate change include the warming of surface water bodies. In recent years several species of blue-green algae began to appear in the Sea of Galilee. These algae produce new toxins and some of them fix atmospheric nitrogen. Until 1994, there was no massive appearance of nitrogen fixing species in the Sea of Galilee and their emergence is a warning sign for changes in the lake's environmental conditions. The blue-green algae prefer relatively high temperatures, which enable rapid growth and toxin productivity. Since these algae are thread algae which are not consumed by zooplankton, their concentration in the water remains high, making it more turbid. The reasons for the changes in species composition in the Sea of Galilee are not clear yet, but they can be attributed, among others, to global warming effects. The implications of this phenomenon include deterioration of water quality in the Sea of Galilee and reduction in the lake's biodiversity.

Climate change may also significantly impact on animal species. Higher temperatures and food availability shortages can contribute to a reduction in the body mass of birds and may have serious implications on bird populations' structure and species competition. Climate changes are among the factors that contribute to the spread and establishment of invasive tropical bird species in Israel. Research has shown that among the new bird species discovered in Israel in the years 1960-2002, tropical species tended to expand and establish their distribution more than the birds from northern origins.

The impacts of climate change on biodiversity also bear an economic cost. These costs include, for instance, damages to tourism due to adverse impacts on nature reserves, efforts to rescue and restore endangered species, loss of water resources in the Sea of Galilee due to water quality deterioration, damage to fishery in the Sea of Galilee and restoration of forests after fire events.

## Energy and Infrastructure

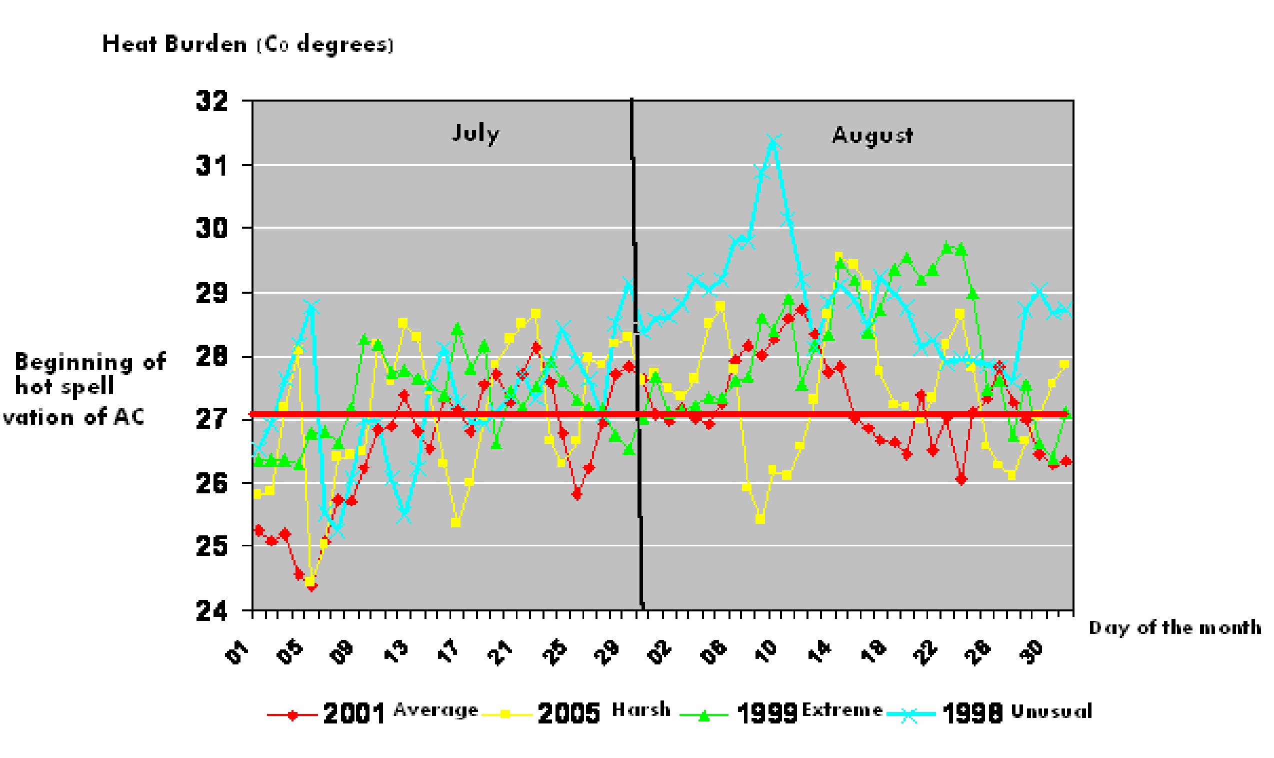
The energy sector contributes approximately 85% of Israel's total greenhouse emissions, originating from fuel combustion, in the various sectors of the economy. Energy production and the production of electricity are the main contributors to the emission of $CO_2$ (73%).

Israel's adaptation report points to the following potential impacts of climate change on energy:

- Electricity demand is expected to grow by 3.2% per year, in a long-term average.
- An increase in peak demand for electricity is expected during heat and cold burdens.

The Israel Electric Corporation is currently preparing for increased energy demand, according to several climatic scenarios, determined by a statistical analysis of the differences between the heat burden in summer on national average, and a 27$^{o}$C heat burden, which is the temperature at which air conditioners are operated (as of 1964-2006). The results of the statistical analysis indicate four possible scenarios for heat intensity in the summer: average, harsh, extreme, and exceptional (Figure 5). The probability for an average, harsh, extreme, or exceptional summer is 53.5%, 27.9%. 16.3% and 2.3%, respectively. The average summer was represented by the year 2001, in which a heat wave lasting 5 days was recorded, with the heat burden peaking at 28.71$^{o}$C on a national average. The harsh summer is represented by the year 2005, in which a heat wave lasting 2 days was recorded, in which the heat burden peaked at 29.55$^{o}$C on a national average. The extreme summer is represented by the year 1999, in which a heat wave lasting 11 days was recorded, with a peak heat burden of 29.7$^{o}$C on a national average. The exceptional summer is represented by the year 1998, in which a heat wave lasting 13 days was recorded, with a peak heat burden of 31.36$^{o}$C on a national average.

**Figure 5 The average daily heat burden during the months of July-August**

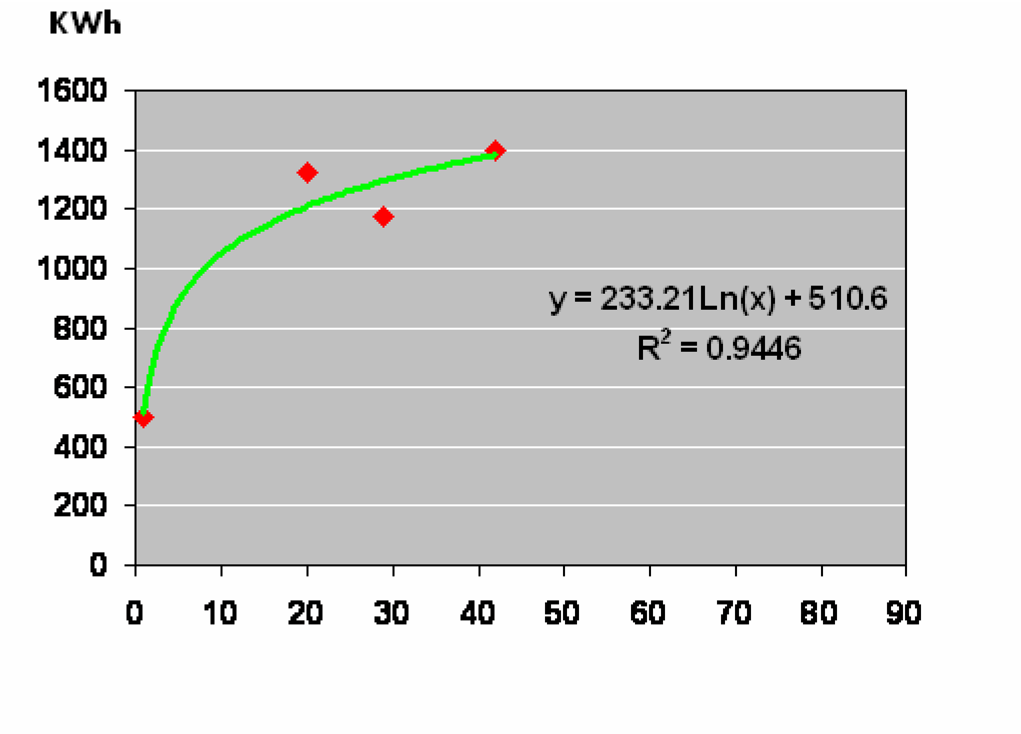



(Source: IEC).

The summer heat burden increases the peak demand for electricity consumption, especially due to the intensive operation of air conditioners. The relation between the electricity consumption of household air conditioners and the heat burden in the third quarter of the year is depicted in Figure 6. For example, if in a given quarter there are 91 days, and in each day the average heat burden is 28 °C, then the sum of differences will be 91*(28-27)=91.

Major parts of the infrastructure in Israel are located in the populated coastal area, which is vulnerable to climate change. Roads, railroad tracks, bridges and ports, industrial centers and power stations are located in areas under threat of sea level rise and extreme events (such as floods). Damage to these facilities due to climate change impacts may bear great economic consequences.

**Figure 6 Electricity consumption and heat burden***




(Source: IEC)

## Economy

Studies suggest that the economic burden of climate changes in the near future will be most significant in the southern Mediterranean basin, due to the structure of the economy of these countries and their geographical exposure to weather damages. Damage to water resources, especially, will affect all economic sectors. The vulnerability of the countries of the southern Mediterranean basin to climate change will vary according to the share of the climate-dependent sectors in the economy, such as for agriculture, tourism, infrastructure, energy, and natural systems.

Although Israel's economy has experienced high growth rates along most of its history, climate change impacts could put an economic burden on the private, business and public sectors and slow down the country's development. The economic implications of climate change on different sectors were briefly described in previous sections.

One of the most vulnerable industries to climate change is the insurance business. Significant damages to public and private property can affect their profitability and their redemption abilities (the ability to pay installments on losses as a result of disasters).

## Adaptation to Climate Change

## Adaptations to climate change

Adaptation is defined as a change in a system's behavior in response to an external stimulus, such as a change in the climate system. Human systems can predict environmental changes, and respond accordingly, and so prepare for the expected changes. The reaction to climate change is on two levels: reaction by precursory actions, in anticipation of change (such as building planning, disaster insurance, and the installation of air conditioning systems), and reaction to the change itself (such as migration from disaster areas, coastal nourishment, and enforcement of building regulations). These tools and methods for coping with anticipated and existing changes have been implemented for years, in the wake of extreme climate events.

Sectors involved with land use, such as agriculture, have managed to cope with climate changes which have taken place gradually and consistently. The key to this success is to identify the signs of change, in order to prepare at the right time, in the right way. In the wake of climate change, which will increase the frequency and intensity of extreme events, it will be necessary to expand or adapt these tools to the new conditions. Climate changes which will occur at a faster rate will make timely adaptation more difficult. Also, extreme events will make adaptation more difficult and more expensive. In addition, it is unclear whether current tools for coping with climatic hazards will be effective or sufficient for dealing with the anticipated climate changes in the long term. For instance, different methods such as genetic alterations of crops and farm animals to reduce vulnerability to stress are only effective if climate changes are not drastic.

The extent of adaptation also depends on the attitude of the public and its willingness to accept the new technologies, or the food engineered by novel technologies (i.e., due to health concerns related to changes in the genetic diversity of plants and aesthetic features).

The need for precursory actions, whose purpose is to avoid the consequences of climate change, must be balanced with the need to respond to these consequences, in order to avoid unnecessary costs. Actions for coping with climate changes could lead to indirect results which should be understood and assessed during the planning process for these actions.

Preparation of a national adaptation plan

The preparation of a framework plan, which will serve as a guide towards successful adaptation for climate change, is highly recommended. By means of such a plan, decision makers will be able to assess the consequences and risks of climate change, and use the existing knowledge in the best possible way. Numerous developed countries have already prepared national plans for coping with climate change, which include the implementation of technology designed to reduce damages to agriculture, protection of coastal areas, and strengthening of infrastructure. In Israel, such a national plan has not yet been prepared, although a government decision calls for the preparation of such a plan in 2010. Since the impacts of climate change are already evident today, and there is a real and actual danger of substantial damages in the short and medium terms, preparatory action must be taken, in order to minimize the expected damages. Adaptation to expected climate change is important in order to prevent large-scale economic and social damages, to develop innovative technologies, and to transfer them to countries at risk of climate change, including developed countries. In addition, preparatory action usually has environmental significance, which is important in and of itself (?).

Based on international recommendations, effective national adaptation must include:

- Means to increase the scientific basis for decision making.
- Methods and tools to assess the adaptation actions.
- Education, training, and public awareness of the importance of adaptation.
- Technological development, effective use of resources and ecological innovation.
- Promotion of local adaptation approaches.
- Legislation and standards that promote environment-friendly adaptation actions.

**Methods and tools to assess the adaptation actions** – The recommendation is to identify climatic conditions which represent data sets of climatic risk, and which will serve as a basis for the development of action policies. These data sets can be based on past experience (such as periods of prolonged droughts), or can describe possible climatic conditions in the future and can provide a basis for the development of practical risk estimates. The risk estimates must include average changes in climatic conditions, such as seasonal temperature increases, as well as changes in extreme weather conditions, such as extreme rain events.

It should be taken into account that adaptation actions could have negative effects. For instance, increased use of pesticides in order to deal with the spread of pests, diseases, and weeds in agriculture, could pollute groundwater, rivers and lakes due to surface runoff, and could threaten drinking water, aquatic habitats and resorts. In addition, when climatic risk is overrated, the results could be excessive adaptations and unnecessary use of resources. It is also possible that adaptation activities will not deliver the expected results, due to the uncertainty of climate conditions in the future.

Risk assessment will also enable the identification of 'no regret' adaptation (choosing the means for adaptation, considered to be beneficial in any possible climatic scenario in the future, including under the present climatic conditions). Nonetheless, in most cases, a 'no regret' decision making process is not possible, and the decision on the nature of adaptation will be uncertain. In this case, the decision will depend on the access of the decision makers to the risk sources (climatic and non-climatic), and to risks accompanying the different solutions.

**Education, training, and public awareness of the adaptation** - It is important to increase public awareness of climate change, including its impacts and the potential means for damage reduction, and to improve the public's understanding of the costs and benefits of the proposed adaptation measures. These actions should be performed in collaboration with non-governmental organizations, educational institutions, and small enterprises, and possibly by means of taxes and incentives. Non-governmental organizations could also act as mediators in the search for technologies, in coordinating investments, and in assisting with technical and administrative issues. Furthermore, skilled personnel should be trained, and access to information on climate change should be provided to the public. The clear goals of the action must be verified, and the message should be conveyed to the public in the best way possible, particularly by the media. The most suitable target audience to which the adaptation message should be transferred should be identified, active participation by interest groups should be encouraged, and the interests of the various stakeholders and sides, which will be affected by the decision, should be taken into consideration.

**Technological development, efficient use of resources and ecological Innovation** – Implementation of a robust environmental policy, free trade and international investments could encourage a more effective global search for resources. Without it, globalization will increase the pressure on the environment. An effective policy is required locally, nationally, regionally, and globally. Globalization could encourage eco-innovation in businesses Environmental efficiency and eco-innovation will not only benefit the environment, but will also increase economic productivity and competition between businesses and countries. Within long-term policy, the cooperation between government and business must be strengthened, and government support of eco-innovation must be provided. Also, environmental costs must be incorporated in the economic activity (e.g., by green taxes), so that green technologies will be able to compete in the market, and business incentives should be provided for such innovation. Increased international environmental cooperation will enable the distribution of best available knowledge, methods, and technologies. For developing countries, this will be an opportunity to learn from the experience of other countries, and to implement clean, energy-efficient technologies, including efficient utilization of resources and implementation of green development methods.

Steps toward preparing Israel's adaptation plan

The aim of Israel's proposed climate change adaptation plan is to integrate preparations for climate change in the strategic planning systems of the various economic, social and environmental sectors. This will be done by the following means:

- Developing means for assessing the implications of climate change, degree of exposure and potential adaptations.
- Assisting the public administration and the civil sector to assess the implications of climate change on their fields of interest.
- Involving Israel's research and development system in assessing the implications of climate change.
- Encouraging the participation of different stakeholders from the general public.
- Mainstreaming the subject of climate change adaptation.

The following actions are recommended:

- Mapping of the degree of vulnerability to climate change
- Assessing economic damages
- Mapping potential action plans for reducing the damage
- Assessing the cost of implementation
- Implementing the necessary organizational changes
- Identifying the main players and their contribution.

In accordance with a government decision on the preparation of a climate change plan for Israel that will include both mitigation and adaptation measures, working groups on adaptation have been appointed which will concentrate on such areas as climate change models, the urban sector, agriculture, biodiversity, public health, drainage and runoff, water resources and economic and insurance aspects. The working groups are charged with bridging the gaps in existing knowledge on the impacts of climate change in Israel based on different scenarios, surveying available means for minimizing damage and vulnerability and identifying Israeli technologies for dealing with climate change that may assist other countries as well.

Implementation of adaptation measures is not an immediate process, but one that evolves with time. In case climate changes will occur at a rapid, continuous rate, adaptation will be more difficult, since it will require faster, more expensive reactions, and it will be difficult to carry out the different actions parallel to the changes taking place. Adaptation once changes have taken place could be more expensive, than advance adaptation, especially due to the effects on long life infrastructure and assets, such as bridges and dams, coastal development, and the planning of floodplains. Early action will facilitate implementation, and will allow for a reduction in costs. It should be recognized, however, that for many actions, time will elapse before the benefits are realized. Nonetheless, taking action in the short term will have long term environmental consequences. The window of opportunity for action is currently open, but will not remain so for long. Withholding action or delaying the implementation of actions will lead to high economic, environmental, and social costs, in the wake of the changes expected already in the near future.

## Recommended actions to prepare for anticipated climate change

Since climate change seems evident and mitigation efforts may not entirely halt the ongoing processes, it is highly recommended that a series of actions be taken to monitor, moderate and prevent some of the global warming impacts. International studies, especially the Stern Review on the Economics of Climate Change have suggested that early proper action can greatly reduce the heavy economic costs of climate change. Therefore, each suggested action should be analyzed in terms of its economic benefits vs. the alternative "no action" option, and feasibility should be estimated in the local context. In addition, an overall analysis of the suggested actions should be conducted in order to prevent negative synergistic impacts of actions or inefficient use of resources. The following section presents a list of suggested actions in major relevant fields.

**Climate monitoring and database**

- Establishment of a database which will concentrate data on climate change. This database should be accessible via internet to the public at large, and should include a complete description of existing data and means of obtaining this data. For example, in the field of atmosphere, a list of meteorological stations, the location of each station, the data measured by each station, the time period for which data exist, the time resolution of the measurements and their accuracy should be included, along with the details of the data holders and means of obtaining the data. It is crucial to allow easy and free access for researchers in the field.

Climate monitoring

- Overall administration of climate research in Israel, which will concentrate the existing studies and will draw the necessary conclusions and requirements.
- Distribution of a larger number of monitoring stations throughout the country. Measurements of air temperature, pressure data in an hourly resolution, hourly precipitation amounts, dust concentrations, altitude cross-sections of pressure, humidity, wind direction and speed, should be included.
- A long-term atmospheric model, at a low time resolution, is required (climate forecast).

Hydrosphere

- Increase in the number of hydrological stations for surface water, which measure the quality and quantity of the water, including monitoring of all potential pollutants, and the flow speed in the channel.

- Sea level temperature measurements in a number of places along the Mediterranean coast, the Red Sea, the Dead Sea, and the Sea of Galilee, at different depths and hourly resolution.
- Measurements of the sea and lake levels and of salinity levels on a regular basis and at a higher resolution.
- Measurements of meteorological and marine data up to a hundred kilometers from the Israeli coasts.
- Measurements of sea level from satellites.
- High resolution aerial photos of specific sensitive areas. For instance, in agriculture, to locate damaged vegetation due to salination or damage to water bodies due to algae bloom or river delta pollution.

## Water Resources

- Incorporating the consequences of climate change (such as decreased water availability, rise in sea level, etc.) into the country's water economy plans, including changes in water abstraction and transport infrastructure as a result of reduced water supply. At present, the Israeli Water Authority is considerably expanding its desalination capacity and is establishing new desalination plants along the Israeli coast in order to cope with the water shortage. In 2008, 150 MCM of desalinated water were supplied (7% of the total water supply). By 2020 desalination capacity is planned to reach 750 MCM.
- Sustainable administration is recommended, which will include flood management, aquatic system protection, and water infrastructure planning. Since many climate impacts are hard to predict, flexible management is required. This will enable the adaptation of preparatory actions to other stress conditions as well. An important tool for long-term planning is the use of different models which predict changes in water resources, in the wake of climate change.
- Ecological models and hydrological models should be integrated. In addition, as changes to present conditions occur, past and present conditions in empirical models could become irrelevant, or useless, in predicting the future. Approaches of mechanistic models and quantitative uncertainty analysis will become more important tools.
- In order to encourage efficient use of water resources and effective management of the water economy, the price of water must be assessed, in a way that internalizes water supply, water usage, sewage treatment, and sewage disposal or reuse. A sustainable water economy requires quantification of externalities in the determination of operational, investment, and pricing policies. These changes lead to an increase in water prices, and means should be taken to ensure that this price increase will not affect the weaker

segments of the population.

- Improvement in the adaptation and coping capabilities of water and sewage infrastructure during flood events.
- Climate change and the population pressure on water resources highlight the need to conserve water and prevent its pollution. A campaign to promote water conservation and correct water consumption is already in place and is helping to prevent careless water use. It should be emphasized that water is an important economic and political resource, which should be used in an efficient, sustainable way, for the benefit of future generations. Water conservation campaigns should also encompass the school system and should use all forms of the media. Water savings may also be encouraged by changes in pricing and taxation.
- Optimal, high quality recycling of sewage. Effluents are currently providing more than 30% of the water consumption in agriculture and 17% of the total water consumption by all sectors.
- Moderation of floods by diverting urban surface runoff to infiltration areas and maintenance of floodplains along rivers. Regulation of floodwater by the expansion of land conservation areas, flooding of more extensive agricultural areas while compensating farmers, and comprehensive management of drainage basins.
- Re-planning of water systems in urban areas in order to increase capacity.
- Improved water use efficiency in urban centers by installing water saving means in households.
- Developing dry gardening that uses water-thrifty plants, instead of flowers and lawns, which require large amounts of water. In addition, an irrigation regime should be put into practice according to season, soil quality, wind regime, etc. These actions could lead to a substantial savings in freshwater consumption.
- Re-assessment of freshwater pollutant lists and drinking water standards and assessment of the potential of climate change to impact on the character and extent of freshwater and aquatic systems pollution.
- Preparations of maps of anticipated land-use patterns for the coming decades (a map for each decade), to enable preparedness for the expected impacts of land-use on water quality, in addition to the consequences of climate change.
- Increased biological monitoring, mapping and collaboration between authorities and bodies responsible for water source management in order to evaluate the health of aquatic systems.

## Agriculture

Crops

- Improvement of the quality of annual forecasts, development of models to predict crop growth, productivity, water and fertilizer consumption, models for pests, insects and plant diseases, and work plans derived from these in accordance with climate changes.
- Addition of variables which present the impacts on agriculture using statistical analysis, such as: frequency and strength of severe heat burden periods and freeze events, frequency of dry spells between rain events, and other events, which affect plant physiology. Improvement of the ability to identify significant trend changes in the relevant variables for climate change in statistical agriculture models.
- Increased use of effluents in Israel as a substitute for freshwater. Connection of all effluent reuse facilities to agricultural irrigation facilities in order to minimize the flow of treated wastewater to the sea. Nonetheless, it is important to irrigate crops with freshwater as well in order to neutralize soil salination and damage to soil fertility from reused water.
- Intensification of water conservation by increasing the use of crops which require lesser amounts of water and whose added value per cubic meter of water is higher (such as wheat, chickpeas, sunflowers, cauliflower, lettuce and garlic), use of saline water, integration of vegetables between rows of orchards and improvement of water technologies in order to improve irrigation efficiency (e.g., pulse irrigation, recovered wastewater and drip irrigation systems).
- Genetic improvement and selection of crops resistant to heat burdens, dryness, and cold, and to the increase in $CO_2$ concentrations. Biotechnology allows for the introduction of species more tolerant to salt and pests and for a general improvement in crop yields and quality.
- Improvement in greenhouses technology, including applying changes to the variety of crops, used inputs, and climate control systems.
- Changes in planting and harvesting dates and selection of a wider seasonal variety. Advancing the planting times of crops could help cope with the rise in temperatures. Nonetheless, not all crops are suitable for this procedure. For example, researchers have found that early seeding is not an effective adaptation measure for wheat and is only slightly efficient for cotton.
- Preference of spring and autumn crops, with a short growth period, in order to avoid the heat burdens of midsummer. Winter crops could become more productive than summer crops.
- Compatibility between the efficient water use of the different crops and selection of

suitable areas to grow those crops.

- Implementation of methods to reduce erosion and prevent soil loss, in addition to increasing the infiltration of water into the fields. The 'no-till' method allows the preservation of the soil and reduction of erosion since there is no soil inversion, and seeding takes place near the vegetation harvested the previous year.

Farm animals

- Improvement of existing climate control systems, improvement of planning and the materials used for livestock farms, shading and the use of sprinkler systems in order to relieve the farm animals of the heat burdens.
- Selection of cattle species more resistant to heat conditions and pests, or genetic improvement of existing species (resistance to heat and pests, and effective food utilization), and timing breeding according to seasonal conditions.
- Development of methods to reduce and/or replace animal feed containing grains, including methods for recycling organic and industrial waste, which will be used as food for farm animals, instead of cereal crops.
- Development of methods to improve the nutrient quality of agricultural and waste by-products, such as straw.

### Coastal Zone

- Incorporation of climate change implications in the land-use planning of the coastal area.
- Continuous monitoring of the rise in sea level along the coast.
- Enforcement to prevent the transfer of alien marine species by trade routes and indirectly (e.g., via bilge water, species arriving with algae, or mollusks, etc.).
- Installation of a salinity barrier in the Suez Canal. An example may be found in the Panama Canal, where an artificial freshwater lake prevents the transfer of marine species. It is possible to install marine barriers along the Suez Canal.
- Assistance in the retreat of coastal ecosystems inland in the wake of sea level rise, by removal of structures that could block the movement inland, or by a re-extension of the coastline by sand nourishment. Nonetheless, these actions are only possible in certain areas, due to the development of many coastal areas.
- Prevention of marine pollution from land sources in the Gulf of Elat in order to reduce the stress on the coral reefs.
- Continued monitoring of the changes to the coastal cliffs, by means of high resolution photogrammetric mapping on an annual basis. One of the more successful options is airborne laser mapping.

- Protection of the coastal cliff by such means as marine protections (detached breakwaters), in combination with sand nourishment. This combined solution requires continuous maintenance by sand nourishment, in order to prevent sand reduction from nearby beaches, as a result of the entrapment of sand by the breakwaters.

## Public Health

- Education and information on potential health damages as a result of climate change.
- Training of health experts in the relevant areas.
- Urban planning to reduce the effect of the urban heat island, which increases heat stress, by means such as tree planting for shading.
- Preparatory actions in the area of air pollution, which will generally benefit the air quality, in addition to contributing to adaptations for climate changes: improvement of air pollution control systems, operation of an alert system for air pollution, limitations on car traffic in densely populated regions, improvement of public transportation and encouragement of car pools.
- Improved border control to prevent the entry of pathogens (including from farm and household animals).
- Increased monitoring of the environment and of various disease carrying vectors.
- Reassessment of clean water criteria (microbial criteria) and risks of water-borne diseases or of disease vectors related to water.
- Prevention of exposure to disease carrying vectors (such as mosquitoes and flies) by limiting their habitats.
- Improvement of the public health systems and their ability to respond to climate change and identification of the vulnerability of certain populations.
- Vaccinations against new or re-emerging diseases.

## Ecosystems and Biodiversity

<u>Biodiversity</u>

- Incorporation of climate change implications in the management of natural reserves to allow for species migration. Ecological corridors between different reserves to enable the increase in the wealth of species and a genetic flow between the areas.
- Greater examination and focus on rare species and highly sensitive ecological communities which require large areas. Larger open spaces increase biological diversity.
- Allocation of conservation areas in the transition zones between the arid climate and the Mediterranean climate – in the northern Negev, in the Judean plain, and east Lachish.
- Allocation of resources for the establishment of a biodiversity monitoring plan, which

will also examine climate changes.

- Treatment of invading species, which contribute to the reduction of local species diversity, and strengthening quarantine methods in ports and borders, through which exotic pest species could enter.
- Mapping the sensitivity of plants and animals to endemic and exotic pests, pathogens and parasites. Preparation of a database and improved monitoring in order to locate in due time pests, plant disease and plant products, which could become harmful under future climate conditions, and improving means of treating these hazards.
- Broadening the scientific knowledge on a variety of strategies effective in the treatment of pests, and their assimilation in practice.

Forests

- Forest management which includes climate change implications under different scenarios, improved knowledge of the climatic requirements of different species, and assessment of the sensitivity and resistance of important species to stress conditions.
- Management of soil resources in the proximity of forests in order to better handle overpopulation and desertification.
- Avoidance of over-exploitation of forest resources.
- Planting of trees resistant to dry conditions and genetic improvement of plant species to allow them to cope with higher temperatures and dryness stress. Such action could help respond to the potential expansion of the desert northward.
- Increasing the $CO_2$ sequestration by forestation and prevention of soil destruction.
- Thinning of forests in order to adapt the number of trees to the habitat conditions. Thinning (reduction in transpiring green foliage per unit area) will allow the water to properly disperse between weeds, flowers, groundwater, etc. Experience during drought years in the past has taught that forests duly thinned survived the drought period, compared to un-thinned forests. Preparedness for forest thinning, including the preparation of an action plan based on knowledge regarding the density of forests in practice, compared to the tree density required, according to the age of the forest and the nature of the habitat.
- Proper understanding of forest health (i.e., drying of trees, damage from forest pests, and defective development of forest trees) is a primary means for planning and taking administrative actions to ensure the resistance and development of the forests in the anticipated dry periods. A more intensive monitoring plan than is currently implemented is required to follow climate dependent processes in the forest.
- Preservation of soil and water resources in the forest. Preservation of water in rainfall areas in the Mediterranean region of Israel, collection of surface runoff water in arid

areas, soil preservation actions for the rehabilitation and stabilization of river beds and slopes, as well as planning and maintenance of roads, may increase the resistance of forest vegetation to reduced precipitation and prevent soil erosion damages. In case the Mediterranean region of Israel will be exposed to the climatic conditions which currently exist in the northern Negev region, it will be necessary to shift the afforestation, water management and soil resources models, which are currently undertaken in the south, northward.

- Actions which could improve the resistance of forests to anticipated fires are improvements in grazing management, treatment of areas bordering built areas, maintenance of forest paths, upgrading the fire engine system and improvement of the training system, implementation of plans to monitor fires in forest areas, and cleaning forests of potential fire hazards, or execution of controlled fires to prevent the accumulation of fire hazards.

### Energy and Infrastructure

- Development and usage of solar energy facilities to deal with the burden on the conventional energy infrastructure as a result of the increased need for air conditioning and for a reduction in greenhouse gas emissions.
- Energy costing to reflect the carbon cost.
- Increased energy efficiency in cities through use of air passageways and insulation measures in building, in order to relieve the heat or cold burdens, and implementation of policies to encourage the efficient use of energy in building, transport, and electricity production.
- Planning and building regulations adapted to the anticipated implications of climate change. Preparations of risk assessments for vulnerable infrastructures, such as roads, railroad tracks, bridges and ports, in areas under threat of extreme events (such as floods). Strengthening and protection of existing infrastructures, and construction according to worst case scenarios of extreme weather events (according to a higher sensitivity threshold of the infrastructure).
- Reduction of industry’s dependence on rare resources.
- Siting of industrial centers far from areas sensitive to weather damages.

### Economy

Insurance companies should prepare for climate change in two ways. The first is adaptation for the adverse effects of climate change on their profitability and on their redemption capacity. An extensive analysis of the potential impacts of climate change on this sector should be performed. Secondly, the insurance sector could aid individuals, governments and private companies to moderate the economic losses. Insurance companies could work toward improving the scientific research on the impacts of the anticipated changes and the means to cope with them, and assist in the funding and development of projects to promote clean technologies and energy-efficient construction. On the other hand, insurance companies could grant economic incentives, such as discounted premiums for those insured who will prepare in due time for the expected changes. These changes could create new business opportunities for the insurance sector, since there are many incentives to develop innovative insurance products to reduce the losses expected as a result of climate change.

### Israel as a Center of Knowledge for Climate Change Adaptation

Based on its rich experience in developing cutting-edge technologies and effective management systems in such fields as water management, recycling and reuse of treated wastewater, seawater desalination, desert agriculture and afforestation, the challenges presented by climate change may well serve as a lever to position Israel as regional and global center of knowledge on adaptation to climate change.

A number of factors combine to make Israel a potential center of excellence on adaptation to climate change, including:

- Israel's existing research capacities in such areas as effluent reuse, irrigation with marginal water, development of drought-resistant crops, desert afforestation and soil preservation.
- Israel's know-how in such fields as water saving in the urban, agricultural and industrial sectors.
- Israel's research and development of innovative technologies in such areas as drip irrigation, leakage prevention, and more.

Israel has checked the feasibility of establishing an information and knowledge center for adaptation to global climate change, based on its broad experience and knowledge in a wide variety of relevant fields, in terms of both management and technology. The establishment of such a knowledge center in Israel may facilitate the collection of information on climate change in Israel and the Mediterranean region, may create climate forecasts together with other countries in the region, may bring together Israel's scientific activities on climate change and may assist in the transfer of Israeli technologies which deal with climate change to countries which currently face the need to adapt to climate change.

**Table 8.1 Summary of Vulnerable Sectors and Adaptation Options**

| Vulnerable Sector | Possible Impacts | Adaptation Options |
|---|---|---|
| **Water Resources** | • Reduction in water availability in aquifers and surface water bodies<br>• Deterioration of water quality<br>• Increased probability of flood events | • Expanding desalination capacity<br>• Efficient water use and effective water economy management<br>• Improved modeling<br>• Increased public awareness and change of consumption patterns<br>• Enhanced water quality and quantity monitoring and modeling<br>• Reassessment of water quality standards<br>• Enhanced collaboration of authorities and the relevant institutions<br>• Improved wastewater and drainage infrastructure<br>• Enhanced management of the land-use interface in flood-sensitive areas |
| **Agriculture** | • Shortage in water supply for agriculture<br>• Damages to crop productivity due to water deficiency and extreme climate conditions<br>• Changes in crop growing seasons<br>• Salination and erosion of soil<br>• Reduced productivity of farm animals<br>• Shortage in fresh animal feed<br>• Increased risks of pests and farm animal diseases | • Increased use of treated effluents in agriculture<br>• Efficient use of water and better adjustment of crop location to water availability<br>• Better modeling and forecasts<br>• Technological improvements in irrigation and cultivation methods and implementation of cultivation methods that prevent soil loss, such as the "no till" method<br>• Genetic improvements in crops and farm animals<br>• Expanding and adjusting the variety of crops<br>• Adjustment of planting and harvesting dates<br>• Improvement of climate control systems in livestock farms<br>• Development of substitutes for grains in animal feed<br>• Selection of cattle species resistant to heat and pests and adaptation of animal husbandry methods |
| **Coastal Zone** | • Coastal retreat<br>• Sand removal<br>• Damages to coastal infrastructure and tourism<br>• Salination of the coastal aquifer<br>• Damages to the coastal | • Incorporation of climate change implications into land-use planning<br>• Enhanced monitoring of sea level and coasts<br>• Adaptation of coastal infrastructure<br>• Using sea protections and sand nourishment techniques<br>• Installation of a salinity barrier in the Suez Canal<br>• Enhanced international trade control in order to prevent |

| Vulnerable Sector | Possible Impacts | Adaptation Options |
|---|---|---|
| | cliff<br>• Increased probability for marine alien species<br>• Coral bleaching in the Red Sea | invasion of exotic marine species<br>• Prevention of sea pollution in order to reduce stress on coral reefs |
| **Human Health** | • Increase in the incidence of parasitic and infectious diseases<br>• Increased thermal stress<br>• Increased risk of damages from extreme weather events | • Enhanced control and monitoring of disease carrying vectors and risk assessment<br>• Training of health experts<br>• Improvement and adaptation of health systems to climate change risks<br>• Public education<br>• Improved urban planning to reduce heat burden and air pollution |
| **Ecosystems & Biodiversity** | • Loss of plant species in the semi-arid region due to desertification<br>• Damage to local animal species populations<br>• Changes in species composition in the Sea of Galilee<br>• Increased likelihood of forest fires<br>• Damages to nature reserves | • Incorporation of climate change implications in the management of conservation areas and the establishment of ecological corridors<br>• Research, monitoring and mapping of species vulnerability to climate change impacts<br>• Enhanced management of forest resources along with their human interface<br>• Forest thinning<br>• Genetic improvements in forest tree species<br>• Selection of resistant tree species for afforestation |
| **Energy & Infrastructure** | • Increased energy demand due to harsher heat burden, particularly during peak heat waves<br>• Damage to infrastructure in vulnerable areas | • Use of alternative energy to meet increased energy demand<br>• Increased energy efficiency<br>• Adaptation of building regulations to new climatic conditions<br>• Identification and protection of vulnerable infrastructure and industries<br>• Enhanced resource management |
| **Economy** | • Damage to public and private property<br>• Increased costs for goods and services<br>• Higher burden on the insurance industry | • Risk analysis for the insurance industry<br>• Cost benefit analysis of adaptation action vs. inaction in selected fields<br>• Economic incentives that promote adaptation to anticipated climatic changes |

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