State of Israel
Ministry of Environmental Protection
Office of the Chief Scientist

Adaptation to climate change in Israel

Recommendations and knowledge gaps

February 2014

Electronic version of the English report: www.environment.gov.il/english
Electronic version of the Hebrew reports of the ICCIC: www.environment.gov.il

---

Translation and Editing: Shoshana Gabbay
Production: Publications, Information and Internet Division, Ministry of Environmental Protection

---

ICCIC Research Team Leaders:
Director of the ICCIC: Prof. Ofira Ayalon
Climate: Prof. Haim Kutiel
Water: Prof. Nurit Kliot
Health: Prof. Manfred Green
Biodiversity: Prof. Marcelo Sternberg
Green Building: Prof. Guedi Capeluto
Local Level Planning and Building: Dr. Tamar Trop
Geostrategy: Prof. Arnon Soffer
Economy: Prof. Mordechai Shechter (former Director of the ICCIC)
Local Level Economy: Dr. Tzipi Eshet

State of Israel
Ministry of Environmental Protection
Office of the Chief Scientist

Adaptation to climate change in Israel

Recommendations and knowledge gaps

Compiled by the Israeli Climate Change Information Center (ICCIC)
Commissioned and Guided by the Office of the Chief Scientist

Presented to the CIRCLE-2 Adaptation Frontiers Conference
on European Climate Change Adaptation Research and Practice

February 2014

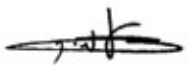
From the Minister of Environmental Protection

The impacts of climate change are evident across the globe. In fact, the recently published scientific report of the Intergovernmental Panel on Climate Change concludes that warming of the climate system is unequivocal and that "most aspects of climate change will persist for many centuries even if emissions of carbon dioxide are stopped." To address the challenges of climate change, both mitigation and adaptation are critical.

The preparation of a vulnerability assessment to climate change and an adaptation plan to confront and minimize the risks is of vital importance to Israel. Therefore, in 2009, Israel's government decided to prepare a national climate change policy and action plan that will include both mitigation and adaptation measures. In the wake of the decision, an Israeli Climate Change Information Center (ICCIC) was set up by the Ministry of Environmental Protection in 2011 to compile the existing knowledge in Israel and abroad, to identify knowledge gaps, and to submit recommendations to the government on national and local adaptation measures. Based on the findings, an interministerial committee on climate change adaptation, which is headed by the Director General of the Ministry of Environmental Protection, is finalizing its recommendations on a climate change adaptation plan for Israel, on both the national and local levels.

Protecting our environment from the impacts of climate change requires regional and international cooperation. Therefore, Israel has also partnered with regional and global organizations to better identify the impacts of climate change and to identify options for mitigation and adaptation. The important link between science and policy making has been especially prominent within the framework of CIRCLE 2 - Climate Impact Research & Response Coordination for a Larger Europe, in which Israel has been an active member. This regional network has been committed to funding research and sharing knowledge on climate impacts, vulnerability and adaptation.

I firmly believe that the knowledge we have accumulated in recent years will allow us not only to reduce the adverse impacts of climate change on our water resources, our health, our biodiversity and our quality of life in general, but will also provide us with new opportunities to find innovative solutions to the challenges ahead. We look forward to continued knowledge exchange and cooperation on climate change adaptation that will yield environmental, social and economic benefits not only to our country but to people everywhere.



MK Amir Peretz
Minister of Environmental Protection

Introduction

Adaptation to the adverse effects of climate change is vital in order to reduce its impacts. Therefore, the Parties to the United Nations Framework Convention on Climate Change have identified adaptation as "one of the five key building blocks" required to strengthen future response to climate change. In recent years, climate change impact assessment, adaptation research and adaptation action have emerged as priority issues on the agenda of governments throughout the world.

As a small, densely populated country characterized by population and economic growth against a backdrop of land and water scarcity, Israel recognizes the importance of preparing for climate change. In June 2009, Israel's government decided on the preparation of a national climate change adaptation program. In accordance with the decision, the Ministry of Environmental Protection set up an Israeli Climate Change Information Center (ICCIC) in 2011 at Haifa University, in cooperation with Tel Aviv University, the Technion – Israel Institute of Technology and the S. Neaman Institute at the Technion. Its mandate is to compile a national scientific base and to prepare policy recommendations that will be integrated into national and local adaptation plans.

Over the past three years, multidisciplinary think tanks, made up of representatives from government, academia, industry and NGOs, have compiled the existing knowledge in such areas as climate, water resources, public health, biodiversity and green building and have analyzed these areas on a multidisciplinary basis using geostrategic and economic perspectives. They identified the risks and implications of climate change and the knowledge gaps in each of these areas and submitted their recommendations on prioritized research requirements, on the proposed national adaptation policy, on ways of marketing the scientific and technological knowledge collated by the ICCIC for application in Israel and around the world, and on the implementation of adaptation measures in local authorities.

An essential component of the work process was the selection of "no regret" alternatives – win-win measures that should be implemented even if the effects of climate change prove to be less severe than predicted.

The findings of the ICCIC are presented in three reports:

- A survey of existing knowledge on the implications of climate change for Israel, based on global and local scientific research and professional publications, identification of knowledge gaps, and recommendations on prioritized research needs to fill the gaps (published in May 2012);
- Policy recommendations and preparation of a plan for international marketing of the products of the ICCIC (published in September 2012);
- A guide on climate change adaptation by local authorities (published in August 2013).

FINDINGS AND RECOMMENDATIONS ON CLIMATE CHANGE ADAPTATION AT THE NATIONAL LEVEL

The northern part of Israel is characterized by a Mediterranean climate and its south by an arid climate, with a narrow, semi-arid strip in between. Frequent weather changes are common in this climate zone due to the effects of climate systems with different synoptic characteristics. This is reflected in significant variations in both temperature and rainfall.

The most crucial component of Israel's climate is the rainfall regime. Changes in the rainfall regime, including annual quantity, number of rain spells, seasonal distribution, intensity and timing, have major impacts on the country's water resources.

Global climate forecasts predict an increase in average annual temperatures of 0.3°C-0.5°C per decade, a reduction in rainfall of 1.1%-3.7%, an increase in the frequency and intensity of heats waves and extreme events such as floods and droughts, and an increase in the probability of forest fires in the Mediterranean region over the next fifty years. In practice, the past four decades have demonstrated an average increase of 0.5°C in temperature per decade in the Mediterranean Sea area.

A trend of rising seawater levels, totaling more than 10 cm, was recorded in the Mediterranean Sea over the past two decades, consistent with scenarios which range from 1 to 10 cm per decade. Such a rise is associated with increased flooding along the coastal plain and increased intrusion of seawater to the coastal aquifer which leads to salinization. Wave storms with wave heights exceeding 3.5 meters have also increased along with exceptional storms with a wave height of more than 6 meters, which are expected to pose major risks to coastal installations and to the collapse of the coastal cliff.

These and other impacts of climate change may have major effects on the water sector, agriculture, public health, biodiversity, the coastal environment and the urban environment in addition to their geostrategic effects and environmental and social impacts.

Following is a survey of the major findings and recommendations of the ICCIC for the different sectors:

Water Resources

Israel's water sector is expected to be highly affected by climate change. Reduced rainfall and increased extreme weather events are likely to increase flooding and surface runoff as well as to reduce water recharge. While desalination and advanced wastewater treatment for agricultural reuse are helping to close the gap between water supply and demand in Israel, they are expensive and energy intensive, resulting in increased emissions of pollutants and greenhouse gases.

Thirty-one strategies for coping with the effects of climate change on Israel's water sector, ranging from the most desirable ("no regret") to the least desirable ("high regret"), were identified by the ICCIC's water sector team. Recommendations call for promoting research and raising public awareness, using water saving devices and minimizing water losses, increasing wastewater treatment, preventing pollution and remediating contaminated wells, advancing water-sensitive planning, promoting rain harvesting, and reusing greywater and treated wastewater. Given the existence of several seawater desalination facilities in Israel, ICCIC experts have classified the building of additional facilities as a "high regret" strategy.

Public Health

Climate change is expected to affect public health directly through physical influences such as extreme heat and cold events and indirectly through the effect on chronic and infectious diseases and on mortality and morbidity from external sources. Extreme weather conditions are known to increase the frequency of certain illnesses, such as cardiovascular and respiratory diseases, while climate change is known to affect the presence and behavior of vector-borne diseases. Other climate factors, such as ultra-violet radiation, are associated with such diseases as cancer and cataracts.

Moreover, climate-induced environmental and ecological changes are expected to change the geographical distribution of diseases and their seasonal patterns.

Since the effects of climate change on the health sector are not fully understood, a "no regret" perspective is advocated based on the allocation of resources for preparatory measures that will have a positive effect on public health, with or without climate change. "No regret" interventions include air pollution improvement, construction of green neighborhoods and support for healthy lifestyles, all of which can reduce the frequency of the risk factors for chronic diseases.

Recommendations call for real-time monitoring and coordinated response to extreme events together with coordinated adaptation to gradual changes in temperature and rainfall which could lead to the outbreak of diseases due to the invasion of new disease vectors. In parallel, the recommendations call for strengthening the preparedness of the health system through such means as personnel training and dissemination of information and guidelines to employees and the public.

Biodiversity

Biodiversity is likely to be extensively affected by climate change, bringing about changes in the geographical distribution of species and in the ecological services provided by natural ecosystems. Ecosystems that will be affected include fresh water ecosystems, marine ecosystems and terrestrial ecosystems. One of the consequences of the anticipated change in the distribution range of species may be an increase in the distribution of tropic arthropods and the consequent spread of disease. On the other hand, populations located in the transition area between Mediterranean and desert climates are characterized by high genetic diversity, and these areas are expected to be of major importance in maintaining biodiversity under climate change.

Since climate change is expected to lead to higher temperatures, greater evaporation and reduced precipitation, the pressures on freshwater systems will increase, aggravating the deterioration of these ecosystems. In addition, specific species or species sensitive to salinity, temperature and/or oxygen concentration may disappear from ecosystems and be replaced by more robust species, either local or invading.

In marine systems, the effects of invasive species in the Mediterranean Sea are expected to accelerate, transforming the Mediterranean ecosystem. The acceleration of seawater acidification may exacerbate the erosion of the sea cliffs and lead to the collapse of the unique abrasion platforms. In the Gulf of Aqaba, coral bleaching may threaten the reef ecosystem.

The complex impacts of climate change on biodiversity and the lack of knowledge on the subject highlight the importance of managing natural ecosystems under conditions of uncertainty. Measures and strategies that are known to have a positive effect on ecosystem stability should be adopted. Recommendations call for "no regret" strategies that include reducing the pressure on freshwater ecosystems and recognizing nature's right to freshwater, conserving open areas and the ecological corridors between them, enforcing laws and policies which prevent adverse effects on open areas, controlling invasive species and dealing with invasive disease vectors, and expanding the scientific base for preparedness through monitoring and research.

Green Building

Green building addresses the dual needs of mitigation and adaptation since the building sector is responsible for about 40% of the global energy consumption and a third of the greenhouse gas emissions. Green building helps reduce greenhouse gas emissions in the long term while responding to the impacts of climate change in the short term. The foundation stones for advancing green buildings include legislation, economic tools, training, and education and information.

The urban system has major impact on the creation of an urban micro-climate. For example, urban morphology and the orientation of the urban network impact on shading and on the exposure of streets and open spaces to sun and wind and contribute to the urban heat island effect. Cities can help reduce greenhouse gas emissions while coping with environmental problems such as air pollution, waste and transportation by promoting the use of alternative energy sources, on the one hand, and by encouraging well-designed cities which reduce urban sprawl, encourage mixed uses, green building and better public transportation, on the other hand.

Recommendations call for establishing a government agency to serve as the hub for sustainable green building in Israel, providing economic incentives for green buildings, applying mandatory regulations for energy rating and tagging new and rehabilitated green buildings, raising public awareness of climate change and sustainable buildings, and incorporating courses on energy-saving buildings, sustainable design and climate change adaptation in institutes of higher learning.

Geostrategy

In the multidisciplinary geostrategy field, three major climate-induced risks are expected to affect Israel – water shortage, rising sea level and rising temperatures. Other areas that may be impacted by the combined effects of climate change include tourism, transportation, energy and national infrastructures, food security, fires, migration and geopolitics.

Despite the potentially profound effects on Israel and its neighbors, insufficient knowledge exists on such issues as the geostrategic balance of power in the Middle East, water resources, migration patterns to, around or through Israel, accelerated energy consumption, food availability

and preparedness of the defense system for the anticipated climatic changes. Israel should take into account the impact of climate change on its domestic and foreign policy and national security, including such issues as the allocation of sufficient domestic resources for future preparedness and adaptation, possible dependence on foreign aid in times of crisis, adjustments within the Israel Defense Forces (IDF) and the defense system as a whole, and more.

The main recommendation is for Israel to transform the threats and risks of climate change into a lever for the advancement of projects that should be carried out in any case, in accordance with the "no regret" strategy: enhancement of water production, preservation of agricultural land, development of a policy on underground construction, securing the food supply and food storage, and securing the energy supply, including local natural gas resources.

Economy

The interdisciplinary economic perspective relates to all the impacts outlined above and estimates their effect on the Israeli economy. While the economic assessment of different adaptation measures has been extensively researched, most studies provide an evaluation at a global or regional level rather than a national or local level. Research on adaptation costs for Israel is scarce, and most of the existing economic studies focus on sea level rise or climate change impact on agriculture. Some recent economic studies employ the "top-down" method of CGE (Computable General Equilibrium) or IAM (Integrated Assessment Models) to evaluate the cost of greenhouse gas mitigation programs or climate change damage costs in Israel.

To help professionals and policy makers identify the most suitable interventions for reducing damage, improving adaptation capacity and increasing resilience, a qualitative assessment of the costs and benefits of adaptation options in the different areas was initiated. Market failures in the adaptation process were identified along with projects and policies that will enhance well-being, even if the climate scenarios are not realized in their full severity ("no regret" strategies).

The next stage in the process should include detailed research on selected adaptation policies, recommendations for appropriate policies, determination of an efficiency index and time range for each type of policy, and an evaluation of the efficiency of the policies.

General Recommendations

The main adaptation policies recommended by the ICCIC include:

- **Enhancement of information availability:** Increasing the availability and dissemination of information on climate change to improve economic efficiency. A "no regret" adaptation policy should focus on those activities that prevent "asymmetric information" that leads to market failures.
- **Water resources strategy change:** Directing efforts toward implementing solutions from least cost to highest cost, with priority to maximizing water supply efficiency, water recycling, water loss prevention and water demand management, and only lastly to investments in additional desalination plants.
- **Regulation that stimulates the autonomous adaptation of markets:** Promoting policies and regulations that support autonomous adaptation actions which would not otherwise be implemented due to lack of public awareness or bureaucratic obstacles.

Similarly, recommendations call for addressing vulnerable areas which have not yet been studied within the framework of the ICCIC, including energy, agriculture, tourism, transportation, and sea level rise.

RECOMMENDATIONS ON CLIMATE CHANGE ADAPTATION AT THE LOCAL LEVEL

Alongside its recommendations on climate change adaptation at the national level, the ICCIC has also addressed the anticipated impacts of climate change at the local level where most climate change impacts are manifested. The most recent report of the ICCIC seeks to delineate a path toward climate change adaptation by local authorities. This is especially important in Israel where some 90% of the population resides in urban localities.

The urban climate has two major characteristics which differentiate it from nearby open areas: an urban heat island and a higher level of pollutants. Research has shown that during the 20th century temperatures in city centers rose by a higher rate than temperatures in adjacent open areas. The combination of urban heat island together with a rise in the concentration of pollutants can lead to a greater frequency of days with high heat burdens and/or days with pollutant concentrations which can be dangerous to public health in general and vulnerable populations in particular.

The ICCIC report on local adaptation presents a series of maps which delineate regions in Israel which are at risk of flooding due to sea level rise and river flooding as well as areas vulnerable to forest fires, dust storms and air pollution. These risk maps are expected to help local authorities better assess their vulnerability to the impacts of climate change – and to act on these assessments by formulating and implementing local adaptation strategies.

Following is a survey of the major recommendations of the ICCIC for local adaptation:

Water

Local authorities in Israel must play a major role in adapting to changes in water sector management. To do this, data on the vulnerability of each locality as well as institutional and research limitations should be gathered. The recommended strategies include:

- Improving the information available to local authorities and the public, promoting education and information on water saving and conservation, and increasing public awareness of the importance of sustainable management of the water sector.
- Promoting water saving and efficiency, using smart water devices, and reducing water losses.
- Treating wastewater and increasing the use of greywater and effluents, including for public gardening, fire-fighting and street cleaning.
- Preventing water pollution and promoting the remediation of wells.
- Promoting rainwater catchment and water sensitive planning.
- Preparing for emergencies including better provision of information to the public.

Health

Emergency centers in local authorities should be established and competent authorities should be designated to deal with the health impacts of climate change including monitoring, education and environmental management. Preparations should take account of both extreme events and gradual climate change. The recommended strategies include:

- Establishing a monitoring system which is accessible to local authorities in real time and includes data on mortality and morbidity, populations at risk and meteorological data.
- Ensuring continuous data collection on the presence of vectors which can serve as disease carriers in different local authorities.
- Providing guidelines to the public and to civil servants on heat waves and cold waves and preparing emergency response plans, especially for vulnerable and high risk groups.
- Providing information to the public and to civil servants on preparedness for climate change through websites, lectures, and more.
- Promoting urban environmental management including green building, maintenance of urban infrastructure, treatment of pest breeding grounds, and air conditioning of public institutions.

Urban Nature and Biodiversity

Increased awareness of the link between urban biodiversity and climate change, as highlighted in the Local Action for Biodiversity (LAB) program, is vital. Therefore, biodiversity considerations should be integrated in local adaptation plans. The recommended strategies include:

- Promoting education and awareness of biodiversity in the urban space, with special attention to the impacts of floods, fires, desertification and invasive species.
- Basing urban planning and ecosystem management on the results of surveys of urban natural assets.
- Conserving urban biodiversity by such means as protected areas around natural assets (such as nature reserves or parks), ecological corridors, and creation and protection of habitats, and reducing the impacts of urban heat islands through urban forestry and green roofs.

Planning and Building

Cities are especially vulnerable to climate change due to the impacts of the urban heat island. To build urban resilience and increase adaptive capacity, both mitigation and adaptation are needed. Local government can play an important role in responding to the challenge of energy efficiency. The recommended strategies include:

- Assessing the risks of climate change at the local level, identifying the main threats and setting priorities for adaptive action.
- Reducing the sources of anthropogenic heat and air pollutant emissions.
- Planning the density and height of buildings in such a way as to reduce the urban canyon effect and improve ventilation and heat and pollutant dispersal.
- Increasing open space and vegetation, including green roofs.
- Using reflective materials which absorb less heat.
- Increasing tree shading along streets and pavements.
- Promoting water sensitive planning.
- Utilizing the underground space.
- Establishing buffer zones to protect cities from fires.
- Adapting existing and future infrastructures.
- Promoting sustainable building though institutional, legislative and economic tools, accompanied by awareness raising, training and research.

Economic Aspects

Investing in the development of an adaptation strategy makes economic sense because the benefits exceed the costs and are expected to lead to future savings as well. Because of the challenges faced by decision makers in deciding on adaptive strategies in the face of major uncertainties in climate change projections and impacts, it is recommended that the most flexible and resilient solutions be chosen for different scenarios. Public-Private Partnerships (PPPs), for example, can play a crucial role in obtaining the necessary funds to address climate change risks and assure the quick recovery of infrastructures.

KNOWLEDGE GAPS AND RESEARCH PRIORITIES

Research on climate change in Israel encompasses studies on observed changes in climatic variables in different periods of time and different geographic areas as well as scenarios of future changes in climatic parameters based on models or on the assumed continuation of trends. However, despite the large number of research studies, the synthesis between observations and scenario-building has proved difficult due to differences in data availability, methods of analysis and periods of research.

Surveying the state of existing knowledge and identifying knowledge gaps and priorities for their closure was one of the first missions of the ICCIC. The following summarizes the knowledge gaps in the different sectors and ranks their research priority in terms of high, medium or low priority.

Knowledge Gaps on Climate in Israel

Knowledge gaps on climate are attributed to missing or inadequate data, inadequate research studies or conflicting findings. For example, one of the basic knowledge gaps relates to the impact of temperature rise on the rain regime in general and on annual quantities in particular. Others relate to the lack of long-term, homogeneous datasets for the rain regime and to the downscaling of global and regional models to reflect local conditions.

Rain Regime

The link between temperature and rainfall:

- Effect of temperature rise on the rain regime (high to medium priority)
- Effect of urbanization on the rain regime in urban and downwind areas (low priority)

Scenarios for different components of the rain regime:

- Downscaling of the number of rain spells (high priority)
- Downscaling of rainfall yields (high priority)
- Downscaling of the duration of the rainy season (medium to low priority)

Temperature

Urban heat island:

- Assessment of the urban contribution to temperature changes (medium priority)

Coastal Environment

- Identification of the synoptic conditions which cause storms with high waves in coastal areas (medium priority)
- The link between sea surface temperature and sea level rise in coastal areas (low priority)

Air Pollution

- Analysis of pollutants concentration time series from different sources (medium priority)

Water Knowledge Gaps and Research Priorities

Knowledge gaps in the water sector include physical/climatic factors as well as anthropogenic factors that impact on Israel's water economy. Therefore, for example, research priorities call for investigating the impacts of changes in precipitation on groundwater recharge, on the one hand, and developing indicators for the success and failure of water saving campaigns, on the other hand. Knowledge gaps largely relate to the effects of precipitation changes on recharge and the effects of rising temperatures on evaporation as well as to water quality issues, drought frequency and duration, runoff monitoring, and water and food safety.

Physical/Climatic Knowledge Gaps

Models

- Downscaling of areas with importance to the water economy (high priority)
- Development of models that link flood tide volumes, rain quantities, their distribution and impact with runoff volume relative to tides (high priority)
- Linking climatic models to hydrological, hydrogeological, ecological and engineering models (medium priority)

Preparedness

- Which scenarios should be prepared for in light of differences in model results (high priority)

Evaporation

- Ground evaporation (high priority)
- Impact of changes in evaporation on agricultural irrigation (medium priority)

Precipitation

- Extreme precipitation events and their impacts on soil, infiltration and recharge (high priority)

Runoff

- Monitoring of urban runoff (high priority)
- Interrelations between runoff and type of soil cover, rain, and soil moisture and between runoff and rainstorms (medium priority)

Collection and Storage

- Feasibility of surface water collection and storage versus infiltration to groundwater (high priority)
- Models for forecasting recharge in aquifers in the coming decades (including soil cover impacts) (high priority)

Temperature Rise

- Impacts of temperature rise on the decomposition of pollutants in rivers and in the Sea of Galilee (Lake Kinneret) (medium priority)
- Impacts of temperature rise on consumption in the urban domestic sector (low priority)
- Impacts of temperature rise on agricultural irrigation needs (low priority)

Drought

- Development of drought indices for Israel (high priority)

Anthropogenic Knowledge Gaps

Anthropogenic Impacts

- Development of methods for distinguishing between global climate change impacts on the water economy and local anthropogenic impacts (high priority)

Wastewater

- Barriers to the use of biogas as an energy source in wastewater treatment plants (medium priority)
- New treatment/purification methods in wastewater treatment plants (low priority)

Wastewater and Effluents

- Feasibility of effluent desalination for infiltration and mixing with fresh water and use of the mix, including for drinking water purposes (medium priority)

Greywater

- Long-term pathogen and epidemiological analysis of greywater systems (medium priority)

Desalination

- Feasibility of desalinating fossil water in the Negev (medium priority)
- Internalization of environmental impacts in the cost of desalinated water (medium priority)

Surface Runoff

- Research on water collection and infiltration upstream (medium priority)

Groundwater Pollution

- Determination of the threshold whereby potable water is no longer potable for each of the natural water sources (high priority)

Urban Water Consumption

- Indicators for the success and failure of water saving campaigns (high priority)
- Review of water loss and improvement indicators (high priority)
- Adoption of economic instruments to increase savings at the domestic level and local authority level (medium priority)
- Pilot study on connecting local authorities to different water sources for emergency preparedness (low priority)

Agricultural Water Consumption, Environment and Security

- Definition of food security including emergency inventory (high priority)
- Feasibility of internalizing the external costs of agricultural production (low priority)

Energy

- Integration of renewable energy in the water economy (medium priority)

Water Geostrategy, Geopolitics and Water Security

- Local and international definitions of water security – new theories (medium priority)

Health Knowledge Gaps and Research Priorities

Knowledge gaps in the area of health mainly relate to the impact of climate change on cardiovascular and respiratory diseases, cancer and cataracts, and foodborne and vector-borne diseases.

Climate Change and Respiratory Diseases

- Development of long-term datasets on the incidence and prevalence of respiratory diseases, in addition to related environmental and social variables (Ayres et al., 2009, Climate change and respiratory disease: European Respiratory Society Position Statement) (high priority)
- Implementation of appropriate statistical methods, such as multilevel regression models for assessing the links between contextual factors and respiratory health outcomes and path analysis for studying possible mediators of these links (Ayres et al., 2009) (high priority)
- Research on the role of climate control systems in buildings in respiratory diseases (Ayres et al., 2009) (medium priority)

Cardiovascular Disease and Stroke

- Focused research on early warning systems and health communications aimed at specific groups that are at increased risk of cardiovascular disease which is related to climate change (Portier et al., 2010, A Human Health Perspective on Climate Change: A Report Outlining the Research Needs on the Human Health Effects of Climate Change) (high priority)
- Increased research on the incidence of cardiac dysrhythmias and their links with temperature and other environmental exposures (Portier et al., 2010) (medium priority)
- Characterization of the multiple individual constituents of air pollution in order to better anticipate the health effects of changing the pollutant mix in the air through the use of alternative fuels (Portier et al., 2010) (medium priority)

Climate Change and Foodborne Diseases

- Understanding and prediction of potential changes in ecosystems due to climate change that may establish new foodborne pathogens, chemical contaminants or biotoxins in addition to new pathways for human exposure (Portier et al., 2010) (medium priority)
- Research on the clinical efficacy of intervention and treatment in relation to climate change, including research on factors, such as the nutritional status, that can increase the sensitivity and efficacy of the treatment (Ayres et al, 2009) (medium priority)
- Understanding the effect of ocean acidification due to climate change related air pollution on the quality and availability of seafood (Portier et al, 2010) (low priority)

Climate Change and Vector-borne Diseases

- Development of a more effective monitoring system for the West Nile Virus by improving its sensitivity and its capacity to detect West Nile Virus circulation at an early stage (European Centre for Disease Prevention and Control, 2011, Consultation on mosquito-borne disease transmission risk in Europe: meeting report) (high priority)
- Assessment of the scope of increased pesticide use (high priority)
- Development of field kits for the identification of vector-borne diseases in the field (medium priority)
- Development of pest control measures for dealing with the anticipated increase in vectors and development of measures for protecting the population (medium priority)

Biodiversity Knowledge Gaps and Research Priorities

There are major gaps in knowledge about the impacts of climate change on biodiversity and ecosystem services in Israel. Research is either missing or inadequate due to the lack of empirical data. This lack of empirical research impairs the ability to forecast the impacts of climate change on biodiversity and to develop adaptation strategies.

Pest Species

- Identification of pests that may spread due to climate change (high priority)
- Impacts of climate change on allergen distribution (medium priority)
- Impacts of climate change on pathogen and parasite behavior in flora and fauna and treatment methods (medium priority)

Invasive Species

- Identification of means to minimize the entry of invasive species (high priority)
- Development of methods to suppress invasive species (high priority)
- Identification of invasive species with significant adverse impacts on natural ecosystems in Israel (medium priority)

Composition of Communities

- Forecasts of changes in vegetation structure, composition of species and diversity of vegetation in different areas (medium priority)
- Assessment of threats to rare species (medium priority)
- Forecasts of changes in the distribution patterns of species (low priority)

Physiological Adaptations

- Resistance of keystone species in the Mediterranean scrub to anticipated climate changes (pine, common oak, gall oak) (medium priority)
- Impacts of climate change on the phenology of flora and fauna (low priority)

Conservation

- Assessment of the potential of *in-situ* conservation under climate change (medium priority)
- Assessment of the potential of *ex-situ* conservation under climate change (low priority)

Ecosystem Services

- Assessment of thresholds of climate variables (temperature, precipitation, evaporation) which may undermine the stability of different habitats (high priority)
- Assessment of ecosystem services provided by natural systems in Israel (medium priority)
- Assessment of different climate change scenarios on ecosystem functioning (medium priority)

Freshwater Habitats

- Effluent use for river rehabilitation (high priority)
- Impact on physical conditions and ecological functioning (medium priority)
- Regularization of rivers in a manner that will conserve their ecological functioning (medium priority)

Marine Systems

- Definition of biological response thresholds (medium priority)
- Development of tools for rehabilitating degraded ecosystems (medium priority)
- Impacts of ecological-climatic-hydrogeographic changes on the multiplicity, reproduction, and availability for fishing of marine organisms (medium priority)
- Understanding the fabric and structure of marine ecosystems in order to forecast changes resulting from climate changes or the invasion of exotic species (medium priority)

Species Interactions

- Forecasts of impacts on pollination and seed propagation (medium priority)

Green Building Knowledge Gaps and Research Priorities

Knowledge gaps on green building relate to the impacts of climate change on the built environment and to the best means of adapting buildings and cities to these impacts. Research is needed to better understand the costs, benefits and efficacy of different adaptation measures for the built environment. Similarly case studies are needed to better understand how best to incorporate climate adaptation into building and city design.

Implementation of Green Building

- Review and analysis of case studies (high priority)
- Cost/benefit analysis in comparison to standard building (high priority)
- Identification of barriers (high priority)
- Monitoring of green buildings – comparison to simulations (high priority)
- Sensitivity analysis of building function relative to user behavior (medium priority)

Energy Savings

- Development of planning guidelines for additional types of buildings (high priority)
- Innovative lighting technologies: quantitative and qualitative aspects (low priority)

Green Roofs

- Review of the impact on energy consumption in a building (high priority)
- Review of the impact on street and city climate (medium priority)
- Implementation potential (medium priority)

Thermal Systems

- Incorporation of thermal systems into the building envelope (medium priority)
- Control systems (low priority)

Energy Renovation of Buildings

- Strategies for energy renovation (high priority)

- Assessment of savings potential in existing buildings (medium priority)

Coping with Extreme Conditions

- Architectural planning for extreme conditions (high priority)
- Urban planning for extreme conditions (high priority)
- Thermal comfort under varying conditions (medium priority)
- Development of urban climate models at the building scale (low priority)

Geostrategic Knowledge Gaps and Research Priorities

Geostrategic knowledge gaps relate both to Israel's national resilience, including infrastructure development and natural resource conservation, and the protection of the country's vital interests in the international arena, including utilization of shared natural resources. Research is needed on the direct and indirect impacts of climate change phenomena such as water scarcity, sea level rise, and temperature rise and global warming on Israel. This requires an understanding of the impacts of climate change on Israel's immediate neighbors (first circle), on neighboring countries bordering the first circle (second circle) and on the rest of the world (third circle).

Water

- Existing data and forecasts of water supply in Israel and the region, including water supply data on the Nile, Tigris and Euphrates Rivers in relation to the geostrategic power balance (high priority)
- Link between climate change and water scarcity and population migration (high priority)

Warming, Aridity and Extreme Conditions

- Tunneling possibilities to cope with conditions of warming and aridity (high priority)
- Link between climate change and fires and models to predict future trends (high priority)

Sea Level Changes

- Forecasts of seawater rise and flooding of the Nile delta (high priority)
- Impact of sea level changes on ports, factories, infrastructures and military facilities along Israel's coasts (medium priority)

Migration due to Climate Change

- Warming and aridity as factors in the movement of populations in Israel from south to north, including the impacts of climate change on the Bedouin population in the south of the country (high priority)
- Migration patterns of Palestinians, Egyptians, Jordanians, Syrians and Lebanese as well as migrants from second and third circle countries into Israel (high priority)

Energy

- Impacts of the wide use of natural gas in Israel on pollutant and greenhouse gas emissions (high priority)
- Research on renewable energy sources and energy cooperation between Israel and its neighbors (high priority)

Food

- Data on food production in Israel and neighboring countries in cooperation with economists (medium priority)
- Food security and climate change with reference to specific food components (medium priority)
- Integrated research on the conservation and development of agriculture as a major supplier of food in Israel (medium priority)
- Relevance of food collection and storage in Israel (medium priority)
- Impact of climate change on fishing in Israel and first circle countries (medium priority)
- Expansion of the food base in Israel with new, available and inexpensive food sources (medium priority)
- Neutralization of the adverse impacts of rising food prices due to climate change on weak socio-economic groups (medium priority)

Security

- Impacts of climate change on logistics, military arming, construction and engineering, human resources, the medical

corps, the air force, basic camouflaging and security (due to forest decline and fires) (medium priority)

- New training regime in the Israel Defense Forces and changes in daily life in the defense system due to climate change (medium priority)
- Protection of facilities such as pipelines, factories, refineries, ports and military bases as a result of rising sea level, at a strategic level (low priority)

Ministry of Foreign Affairs

- Climate change as an information tool to highlight Israel's achievements in the area of climate change adaptation and assistance to neighboring countries (high priority)
- Potential regional cooperation in the wake of climate change (medium priority)
- Probability of international aid to Israel in case of a natural disaster related to climate change (medium priority)

Economic Knowledge Gaps and Research Priorities

Numerous knowledge gaps were identified with regard to the economic implications of adaptation measures in Israel. Most of the existing economic studies for Israel focus on sea level rise or the impact of climate change on agriculture, with limited information on other sectors of the economy. Research gaps relate to the empirical assessment of adaptation costs, impacts on different economic sectors, model-based quantitative research, and the effects of uncertainty on the costs of adaptation and policy measures.

- **Empirical Assessment of Adaptation Costs in Israel:** General research including assessments that integrate bottom up and top-down approaches (high priority)
- **Economic Research at the Sectoral Level and Case Studies:** Research on the impact of different sectors on the economy: water, health, ecosystems, geostrategy, green building, insurance, agriculture, coastal protection (sea level rise), tourism and transportation (high priority)
- **Model-Based Quantitative Research on the Integration of Adaptation and Mitigation Strategies:** Model-based quantitative research adapted to Israel's economy on the impact of mitigation policy on adaptation policy (high priority)
- **Research on the Uncertainty of Climate Change and its Impact on Adaptation Costs and Policy:** Research on uncertainty in climate change and its impact on cost assessments and the selection of policies in Israel, including the insurance sector (high priority)
- **Timing of Adaptation Measures:** Research on the optimal timing of implementing adaptation strategies in Israel (medium priority)
- **Comparative Research of Adaptation Policies:** Review of adaptation policies in different countries that are relevant to Israel's economy, especially based on the OECD report on adaptation policies (with emphasis on economies similar to Israel) (medium priority)
- **Types of Adaptation Strategies: Autonomous/Planned, Anticipatory/ Reactive, Private Public:** Review of adaptation strategies that are relevant to Israel (low priority)

THE PATH FORWARD

It is well-recognized that despite the uncertainties, it is imperative to develop adaptation strategies to cope with the existing and forecasted climate change impacts. Based on an analysis of available knowledge, Israel has identified “no regret” and “low regret” options that will yield benefits even in the absence of climate change. Acting on these options will not only minimize climate risks but have social, environmental and economic benefits. In parallel, Israel has identified knowledge gaps that will hopefully be filled in coming years so as to enable it to better prepare for the impacts of climate changes.

In order to accelerate the formulation of a climate change adaptation plan for Israel, an interministerial committee on climate change, composed of the directors general of relevant government ministries and headed by the Director General of the Ministry of Environmental Protection, was appointed. It is currently finalizing its recommendations on a climate change adaptation plan which will be presented to the government. The goal is to link science and policy by mainstreaming research-based adaptation strategies into master plans and action plans in a wide range of fields, including water, agriculture, biodiversity, green building, economy, public health and more.

ecological paper

www.environment.gov.il