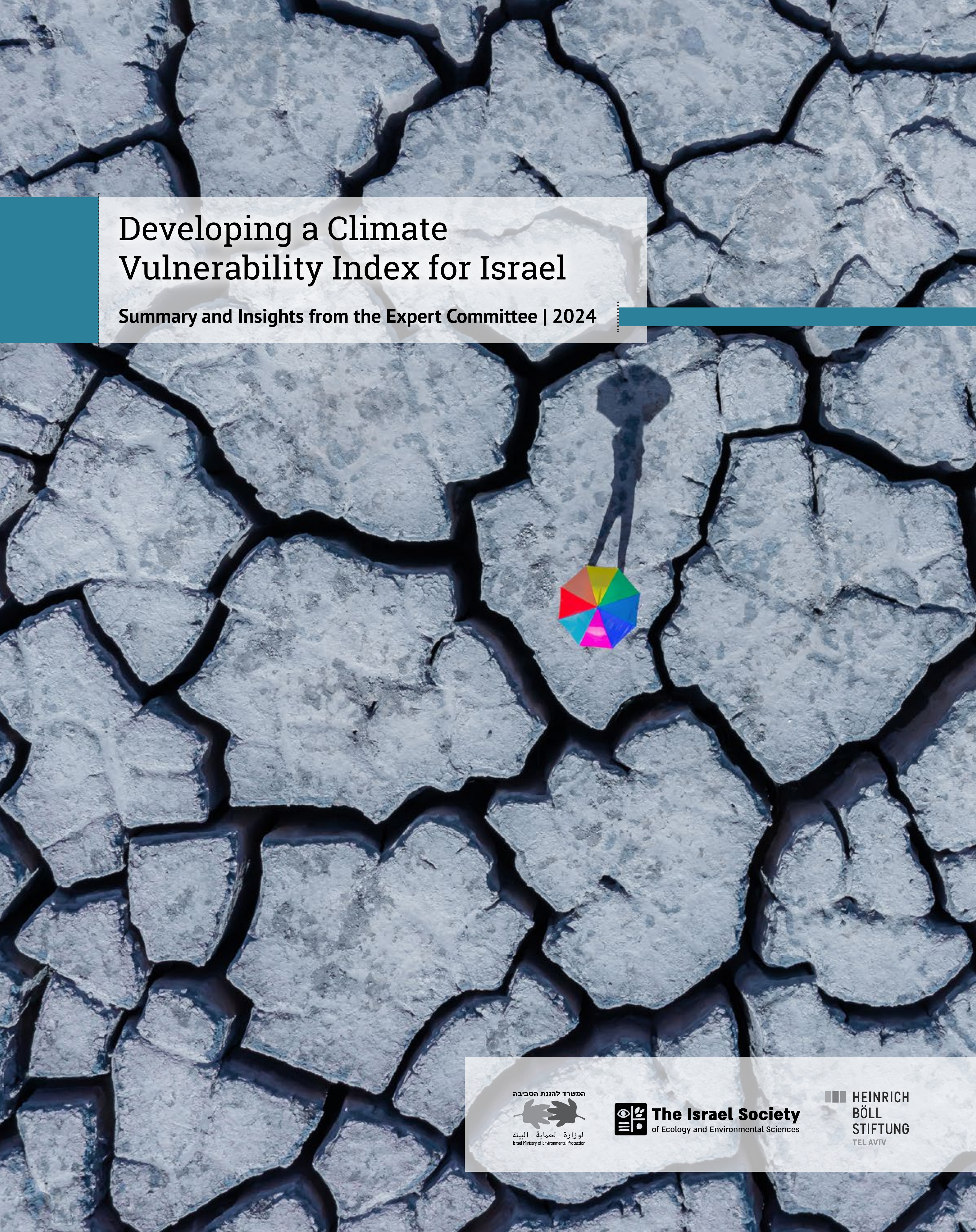


Developing a Climate Vulnerability Index for Israel

Summary and Insights from the Expert Committee | 2024

המשרד להגנת הסביבה
وزارة حماية البيئة
Israel Ministry of Environmental Protection

The Israel Society of Ecology and Environmental Sciences

HEINRICH BÖLL STIFTUNG TEL AVIV

Editor and Main Author: Dr. Ben Belek

Committee Staff: Prof. Noga Kronfeld-Schor, Dr. Amiel Vasl, Dr. David Dahan, Dr. Ronit Ratzon, Dr. Ori Sharon, Romy Shapira, Gal Tamir, Omri Carmon, Gili Cohen

Assisted with Writing and Data Collection: Dr. Tal Ulus, Gili Cohen, Yarden Menelzon, Dana Marminsky

Assisted in the Discussions: Gili Cohen, Dr. Yahala Dor, Luce Mitelman, Vicki Katz, Noa Weinberg, Lotem Biderman

Committee Participants (in alphabetical order): Hila Ackerman[50], Noga Adler Shtern[3], Dr. Keren Agay-Shay[2], Yafit Alfandari[4], Liat Arbel[5], Daphna Aviram-Nitzan[1], Orly Babitsky[30], Tomer Barak[15], Dr. Idan Barnea[14], Prof. Jonathan Belmaker[7], Shachar Ben Zvi[8], Andy Benica[9], Prof. Oded Berger-Tal[10], Dr. Daniel Berkowic[45], Dr. Ella Brand Levy[13], Emri Brickner[12], Prof. David Broday[11], Prof. Eli Bukspan[6], Omri Carmon[10], Ran Cohen[16], Yaara Dagoni[3], Dr. David Dahan[17], Dr. Ayelet Davidovitch[7], Prof. Nadav Davidovitch[10,40], Dr. Shira Efron[26], Dr. Shlomit Flint Ashery[2], Dr. Naomi Fliss Isakov[36], Prof. Eran Friedler[11], Avner Furshpan[34], Dr. Benny Furst[39], Gedi Ganir-Abadi[32], Dr. Uri Grupel[16], Guy Harel[46], Idit Hod[18], Dorit Hizi[12], Dr. Roy Jaijel[20], Dr. Yael Kachel[22], Matan Kaiserman[38], Yuval Kalush[38], Dr. Orr Karassin[39], Dr. Isabella Karakis[36], Galit Kenigsberg[7], Dr. Karni Krigel[2], Dr. Lea Kronaveter[23], Prof. Noga Kronfeld-Schor[17], Prof. Itamar Lansky[2], Dr. Adi Levi[24], Dr. Doron Levin[26], Prof. Hagai Levine[27],Dr. Shay Levy[25,35], Dr. Moshe Mandelmilch[11], Prof. Ron Milo[28], Dr. Noga Naor[29], Prof. Jonathan Natanian[11], Prof. Maya Negev[30], Alaa Obeid[33], Alix Pahaut[30], Dr. Ruslana Rachel Palatnik[35], Dr. Renana Parzanchevski Amir[21], Prof. Shlomit Paz[30], Prof. Oded Potchter[7], Uri Ramon[48], Dr. Carmit Rapaport[30], Dr. Ronit Ratzon[36], Dr. Yair Rinat[23], Orit Roffe[32], Dr. Uri Roll[10], Dr. Orli Ronen[7], Naama Rotem[4], Maya Sadeh[40], Roy Sahaf[41], Dor Sandler[7], Nimrod Sapir[31], Eli Schwarzer[26], Dr. Miri Shachar[36], Naama Shapira[42], Dr. Stav Shapira[10], Romy Shapira[43], Dr. Ori Sharon[2], Michael Sherman[44], Dr. Anna Shnaidman[37], Dr. Naomi Shpirer Belfer[49], Gal Tamir[17], Dr. Eran Tas[27], Prof. Anat Tchetchik[2], Dr. Naama Teschner[10], Dr. Gidon Toperoff[22], Dr. Nirit Topol[21], Jonathan Tryfus[23], Dr. Amiel Vasl[17], Dr. Enav Vidan[10], Aviva Weiss[47], Amit Yagur-Kroll[4], Prof. Dan Yakir[28], Dr. Moshe Yanai[4], Dr. Shiri Zemah Shamir[6], Prof. Shlomit Zuta[19], Amit Zvigoren[37].

Institutional Affiliation of Participants: [1]The Israel Democracy Institute, [2]Bar-Ilan University, [3]The Ministry of Welfare and Social Affairs, [4]The Central Bureau of Statistics, [5]Council for a Beautiful Israel, [6]Reichman University, [7]Tel Aviv University, [8]The Ministry of Finance, [9]Yad Hanadiv, [10]Ben-Gurion University of the Negev, [11]Technion - Israel Institute of Technology, [12]The Public Knowledge Workshop, [13]The Joint (JDC), [14]Society for the Protection of Nature in Israel, [15]Gazit Institute, [16]The Ministry of Labor, [17]The Ministry of Environmental Protection, [18]Forum 15, [19]The Academic College of Tel Aviv-Yaffo, [20]Agma – The Israeli Watersheds and Rivers Center, [21]National Academy of Sciences, [22]The Ministry of Agriculture and Rural Development,

[23]The Governmental Water and Sewage Authority, [24]Achva Academic College, [25]National Fire and Rescue Authority, [26]The Ministry of Defense, [27]Hebrew University of Jerusalem, [28]Weizmann Institute of Science, [29]The Ministry of Transportation and Road Safety, [30]Haifa University, [31]Israel Investment Houses Association, [32]National Emergency Management Authority, [33]The Galilee Society, [34]Israel Meteorological Service, [35]Max Stern Yezreel Valley College, [36]The Ministry of Health, [37]Survey of Israel, [38]Directorate for Defense Research and Development (DDR&D), [39]The Open University of Israel, [40]Taub Center for Social Policy Studies in Israel, [41]Tomorrow.ie, [42]Samuel Neaman Institute, [43]Heinrich Böll Foundation, [44]The Ministry of Energy and Infrastructure, [45]Environemntal Advisor, [46]Israeli Defense Forces, [47]Capital Market Authority, [48]Open Landscape Institute (OLI), [49]Harel Center for Capital Markets Research, [50]Regional Authorities Center in Israel.

English Translation: Dr. Hilit Finkler

Graphic Design: Tamar Rosner-Peretz

Cover Photo: Gilad Topaz

Recommended Citation: Ben Belek, Amiel Vasl, Gal Tamir, Omry Carmon, David Dahan, Ori Sharon, Ronit Ratzon, Romy Shapira, Gili Cohen, Yarden Menelzon, Tal Ulus, Dana Marminsky and Noga Kronfeld-Schor (2024). Developing a Climate Vulnerability Index for Israel: Summary and Insights from the Expert Committee. The Israel Society of Ecology and Environmental Sciences, Heinrich Böll Foundation, and the Ministry of Environmental Protection. 86 pages.

We thank the Steinhardt Museum of Natural History in Tel Aviv for hosting the committee discussions panel.

Table of Contents

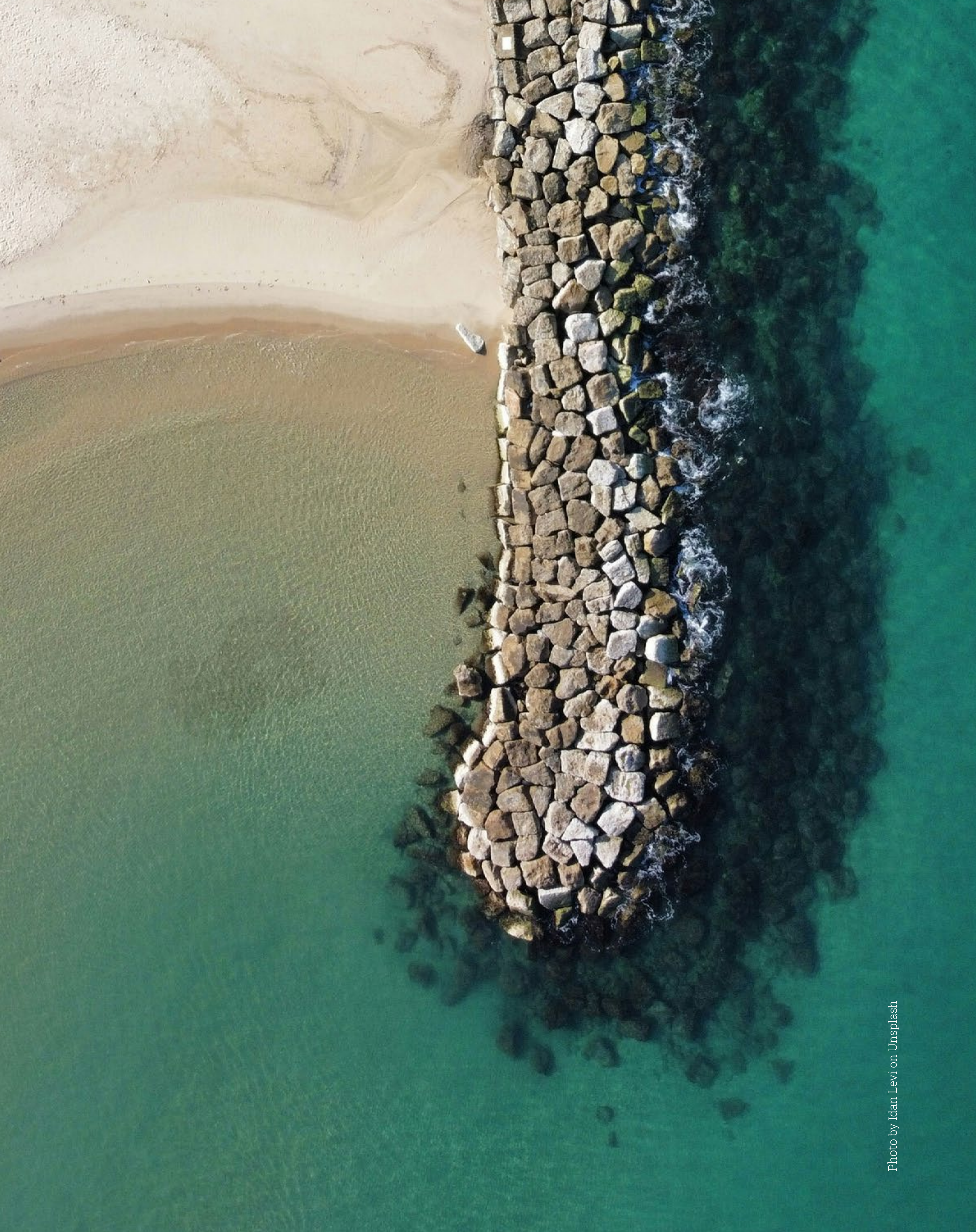


Photo by Idan Levi on Unsplash

About the Expert Committee

The Expert Committee on Developing a Climate Vulnerability Index for Israel is a collaborative initiative between the Israel Society of Ecology and Environmental Sciences (ISEES), the Chief Scientist in the Israeli Ministry of Environmental Protection, and the Heinrich Böll Foundation. This joint effort aims to identify key vulnerability indicators for inclusion in Israel's national climate vulnerability index.

ISEES is dedicated to advancing the scientific community and enriching climate and environmental policies in Israel. ISEES focuses on providing scientific solutions for natural resource management and environmental policy formulation by fostering collaborations between policymaking bodies and scientists. To facilitate such collaborations, ISEES establishes expert committees, which serve as forums for deliberation and knowledge exchange among different stakeholders.

During a day-long roundtable discussion, leading scientists from relevant fields, alongside government administrators, business professionals, and civil society representatives, deliberated on the multifaceted aspects of climate change vulnerability. This exchange of knowledge and insights has culminated in this comprehensive report: an actionable, science-based foundation for the development of a national climate vulnerability map.

Photo by Lio Voo

Executive Summary

Background

Israel is in a region classified as a hotspot area for climate change. Yet the expected impacts of climate change are not determined merely by the level of exposure to changing climate conditions, but also by the vulnerability and sensitivity levels of individuals, communities, and systems in the exposed areas. In short, vulnerable populations face greater risks. Without adequate adaptation efforts, climate change is likely to exacerbate social disparities based on economic, ethnic, gender, and health factors, leading to increased social inequality.

Evaluating the vulnerability of communities and systems to climate change requires a thorough analysis of the unique vulnerability characteristics of different regions. To conduct such an analysis in a standardized and reliable manner, the development of a vulnerability index is necessary. This index would provide a comprehensive characterization of the various sensitivity characteristics (environmental, social, economic, and health) of different communities and regions. It would be based on existing databases readily available to authorities and research institutions, as well as on the collection of new data.

In essence, a climate vulnerability index is a methodological tool designed to organize existing information, select the most relevant and reliable data, and use a weighing key to process it into standardized values. This facilitates comparisons between different geographic units and the communities inhabiting them, thereby prioritizing the communities, sectors, and systems most vulnerable to climate change. Moreover, the use of an index supports concerted efforts to reduce vulnerability and enhance climate resilience.

A vulnerability index typically consists of three components: the exposure component, the adaptive capacity component, and the sensitivity component. Each of these components consists of a varying number of indicators, grouped into fields and clusters. The weighing process of all indicators produces a final value that represents the vulnerability level of a certain area to climate change. Choosing the indicators that comprise the index is the first essential and indispensable step in its development.

The aim of the expert committee is to characterize and select the most appropriate indicators, thereby establishing a scientific, professional infrastructure for developing a climate vulnerability index for Israel.

Main Findings of the Expert Committee

The expert committee for the development of the Israeli climate vulnerability index convened on 30 April 2023 at the Steinhardt Museum of Natural History in Tel Aviv. The committee comprised experts from various research institutes, government authorities, and civil society organizations, along with selected representatives from the defense system, local government, and industry. More than 100 experts participated in the day of discussions, divided into five roundtables. Each roundtable, led by specialist experts who volunteered for this task, held a three-hour discussion in their respective fields. Alongside the identification of challenges, limitations, needs, and opportunities in developing the vulnerability index, experts were asked to compile a list of potentially relevant indicators for each of the four sensitivity fields comprising the sensitivity component of the index. In total, 130 indicators were selected.

Socio-economic sensitivity: Twenty experts participated, facilitated by Gal Tamir from the Ministry of Environmental Protection. Twenty-two indicators were selected.

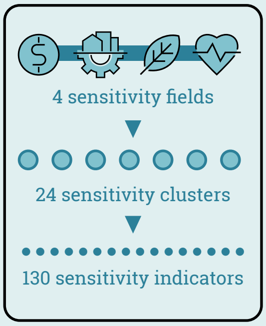
Operational continuity sensitivity: Twenty-one experts participated, facilitated by Dr. Ori Sharon from Bar-Ilan University. Sixty-three indicators were selected.

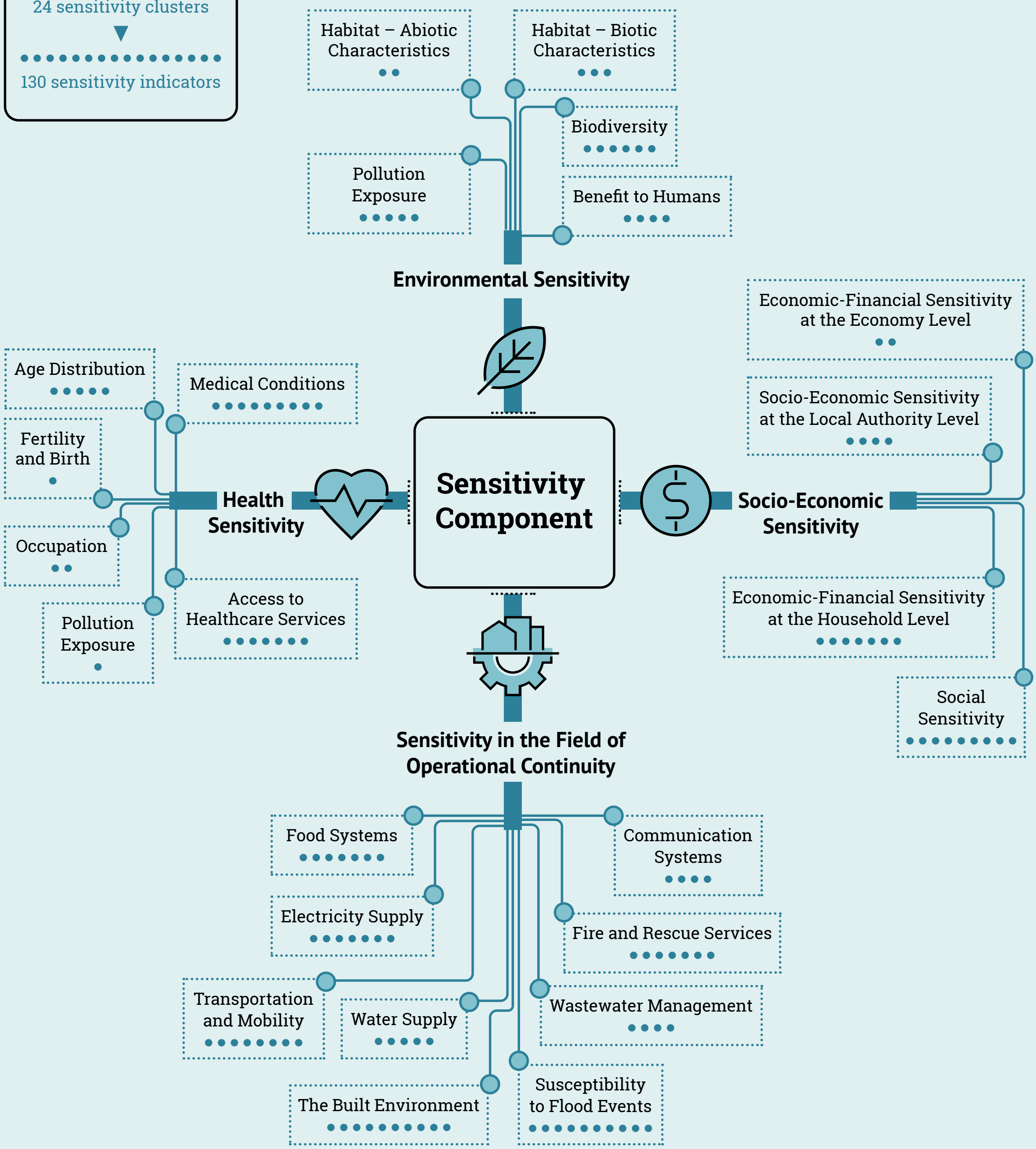
Health sensitivity: Sixteen experts participated, facilitated by Dr. Ronit Ratzon from the Ministry of Health. Twenty-five indicators were selected.

Environmental sensitivity: Seventeen experts participated, facilitated by Dr. Amiel Vasl from the Ministry of Environmental Protection. Twenty indicators were selected.

Integration of sensitivity fields: Twenty-three experts participated, facilitated by Omri Carmon from Ben-Gurion University.

Below is the detailed list of selected indicators for each field:


4 sensitivity fields
24 sensitivity clusters
130 sensitivity indicators


Sensitivity Component
Environmental Sensitivity
Habitat – Abiotic Characteristics
Habitat – Biotic Characteristics
Biodiversity
Pollution Exposure
Benefit to Humans
Health Sensitivity
Age Distribution
Medical Conditions
Fertility and Birth
Occupation
Pollution Exposure
Access to Healthcare Services
Socio-Economic Sensitivity
Economic-Financial Sensitivity at the Economy Level
Socio-Economic Sensitivity at the Local Authority Level
Economic-Financial Sensitivity at the Household Level
Social Sensitivity
Sensitivity in the Field of Operational Continuity
Food Systems
Communication Systems
Electricity Supply
Fire and Rescue Services
Transportation and Mobility
Water Supply
Wastewater Management
The Built Environment
Susceptibility to Flood Events

Chapter 1: Socio-Economic Sensitivity

This chapter focuses on evaluating the sensitivity of diverse populations to the impacts of climate change, particularly in terms of social and economic aspects. In the expert discussion, 22 indicators were selected for this field, organized into four clusters: social sensitivity, economic-financial sensitivity at the household level, economic-financial sensitivity at the economy level, and socio-economic sensitivity at the local authority level. Below are the sensitivity clusters discussed for the socio-economic sensitivity field, along with the suggested indicators for each cluster:

1 Social Sensitivity

This cluster examines the ability of individuals and households to rely on social capital resources for adapting to climate change and coping with its impacts.

The indicators proposed for this cluster are as follows:

a. Proportion of single-parent households
b. Proportion of immigrants
c. Proportion of elderly people without family suppor
d. Proportion of unhoused people
e. Education level
f. Degree of gender inequality
g. Age distribution
h. Access to information and knowledge about services
i. Proportion of individuals from minority groups

2 Economic-Financial Sensitivity at the Household Level

This cluster assesses the presence or absence of financial safety nets in the case of extreme events.

The indicators proposed for this cluster are as follows:

a. Socio-economic level
b. Liquid assets
c. Low liquidity assets
d. Degree of insurance coverage
e. Housing cost burden
f. Small business ownership
g. Real estate prices

3 Economic-Financial Sensitivity at the Economy Level

This cluster considers the presence of vital sites within an area, the closure of which could result in significant national economic losses.

The indicators proposed for this cluster are as follows:

a. Concentration of vital infrastructures
b. Density of high value assets and activities

4 Socio-Economic Sensitivity at the Local Authority Level

This cluster focuses on the degree of anticipated economic loss to the local authority resulting from extreme climate events.

The indicators proposed for this cluster are as follows:

a. Proportion of small businesses
b. Peripherality index
c. Ratio of residential to commercial and industrial areas
d. Population density

Chapter 2: Sensitivity in the Field of Operational Continuity

Operational continuity sensitivity refers to the ability of authorities to maintain and deliver essential services to communities during crises. In the expert discussion, 63 indicators were selected, organized into nine clusters: water supply, electricity supply, transportation and mobility, food systems, fire and rescue services, wastewater management, communication systems, the built environment, and susceptibility to flood events. Below are the sensitivity clusters discussed for the field of operational continuity, along with the suggested indicators for each cluster:

1 Water Supply

This cluster assesses the sensitivity of the local water supply system to extreme climate events, while considering its dependency on other systems, primarily the electricity system.

The indicators proposed for this cluster are as follows:

a. The city's water storage capacity
b. Water quality in the city's water storage system
c. Level of dependency of the local water supply on the national supply system
d. Energy security of desalination facilities, wells, and pumping stations
e. Energy security of water systems in high-rise buildings

2 Electricity Supply

This cluster assesses the sensitivity of the local electricity system to extreme climate events while considering its critical role in maintaining the operational continuity of other systems.

The indicators proposed for this cluster are as follows:

a. Energy storage capacity in a specific area
b. Proximity to energy production sources
c. Proportion of production systems susceptible to reduced output due to rising temperatures
d. Response time to power outage events by area and event scale
e. Supply-demand ratio per region
f. Presence of energy production facilities in high-risk areas
g. Availability of technical teams in high-temperature conditions

Transportation and Mobility (3)

This cluster assesses the transportation system's sensitivity to extreme climate events.

The indicators proposed for this cluster are as follows:

a. Access to public transportation
b. Proportion of electric vehicles
c. Resilience of roads and railroads to extreme events
d. Level of backup energy generation capacity for electric trains
e. Distance from critical emergency centers
f. Number of access points to the area
g. Critical transportation infrastructure susceptible to flooding
h. Measure of walkability

Food Systems (4)

This cluster assesses local food production, transport, and distribution systems' sensitivity to extreme climate events.

The indicators proposed for this cluster are as follows:

a. Share of agricultural crops protected by climate mitigation measures
b. Share of agricultural crops grown in climate adaptive interfaces
c. Crop diversity per geographic unit
d. Sensitivity of agricultural crops to reduced water supply
e. Sensitivity of agricultural crops to extreme events during critical periods
f. Degree of dependence on refrigeration during transportation, storage, or processing
g. Degree of dependence on import from countries with high climate vulnerability
h. Share of agricultural land covered by comprehensive insurance

Fire and Rescue Services (5)

This cluster assesses the availability of fire and rescue services, the effectiveness of fire prevention measures, and the fire risk posed to structures and areas.

The indicators proposed for this cluster are as follows:

a. Age of structure
b. Structure density
c. Water availability for firefighting efforts
d. Quality and availability of firefighting services
e. Level of fire risk
f. Frequency of fire events
g. Number of residents per housing unit

Wastewater Management (6)

This cluster assesses the proper functioning of wastewater management systems during extreme climate events.

The indicators proposed for this cluster are as follows:

a. Energy security of wastewater pumping stations
b. Size of wastewater treatment facilities
c. Energy security of wastewater treatment facilities
d. Susceptibility of wastewater treatment facilities to flooding

7 Communication Systems

This cluster assesses communication systems' sensitivity to extreme climate events.

The indicators proposed for this cluster are as follows:

a. Readiness of backup systems for emergency events
b. Level of maintenance of the physical communication infrastructure
c. Physical access to infrastructure during an emergency
d. Susceptibility of communication centers to flooding

9 Susceptibility to Flood Events

This cluster assesses the level of sensitivity of a geographical area to damage resulting from floods.

The indicators proposed for this cluster are as follows:

a. Proportion of built areas lower than their surroundings
b. Proportion of built areas in surface depressions
c. Proportion of built areas located in a floodplain
d. Proportion of urbanized areas at risk of flooding due to rising sea levels
e. Susceptibility to accessibility constraints during flood events
f. Efficiency of drainage infrastructures
g. Proportion of impervious surface
h. Frequency of insurance claims for flood-related damage
i. Frequency of emergency rescue calls related to flooding
j. Distance from specialized rescue teams

8 The Built Environment

This cluster assesses various characteristics of the built environment that can increase or reduce an area's sensitivity to climate change.

The indicators proposed for this cluster are as follows:

a. Age of structure
b. Implementation of SI 5281 Green Building Standard
c. Proportion of tall buildings
d. Building rating according to Neighborhood 360°
e. Underground infrastructure allocation
f. Above ground infrastructure in flood prone areas
g. Proportion of urban shaded areas
h. Proportion of green spaces
i. Proportion of households without access to the electricity grid
j. Proportion of housing units with air conditioning and operational capacity

Chapter 3: Health Sensitivity

The health sensitivity field evaluates the vulnerability of populations, communities, or individuals to the adverse health effects resulting from climate change. During the expert discussions, 25 indicators were selected for this field, organized into six clusters: age distribution, medical conditions, fertility and birth, access to healthcare services, pollution exposure, and occupation. Below are the sensitivity clusters discussed for the health sensitivity field, along with the suggested indicators for each cluster:

1 Age Distribution

This cluster considers the heightened sensitivity of children and elderly people to the negative impacts of climate change.

The indicators proposed for this cluster are as follows:

a. Adults over 70
b. Adults between 50-70
c. Youths under 18
d. Children under 5
e. Infants under one year

2 Medical Conditions

This cluster refers to the increased sensitivity to climate change of individuals suffering from certain medical conditions.

The indicators proposed for this cluster are as follows:

a. Nonaccidental death rate
b. Respiratory disease prevalence
c. Heart disease prevalence
d. Psychiatric morbidity rate
e. Allergy prevalence
f. Obesity rate
g. Cancer prevalence
h. Diabetes prevalence
i. Hypertension prevalence

3 Fertility and Birth

This cluster considers the heightened sensitivity of pregnant women to the negative impacts of climate change.

The indicator proposed for this cluster is:

a. Proportion of pregnant women

4 Access to Healthcare Services

This cluster assesses the degree of access to various healthcare services, a factor that significantly influences a community's sensitivity to climate change.

The indicators proposed for this cluster are as follows:

a. Health literacy rate
b. Access to digital health services
c. Physical access to community health services
d. Physical access to emergency health services
e. Prevalence of mobility difficulties
f. Prevalence of communication difficulties
g. Quality measures in community medicine

5 Pollution Exposure

This cluster relates to exposure to pollution, a major health risk for numerous diseases, thereby increasing sensitivity to climate change.

The indicator proposed for this cluster is:

a. Level of air pollution exposure

6 Occupation

This cluster considers the occupational characteristics that could affect an individual's sensitivity to the negative impacts of climate change.

The indicators proposed for this cluster are as follows:

a. Proportion of individuals working in construction or agriculture
b. Number of construction sites involving elevated work or infrastructure development

Chapter 4: Environmental Sensitivity

The field of environmental sensitivity involves evaluating and characterizing the expected negative impact of climate change on the environment in Israel. Climate change poses a significant threat to biodiversity, and its impact is expected to worsen over time. Climate change compounds existing pressures on ecosystems, intensifying challenges faced by biodiversity, such as diminishing natural open areas, overexploitation of natural resources, and pollution of water, soil, and air, as well as an increase in invasive species. During the expert discussions, 20 indicators were selected for this field, organized into five clusters: biodiversity, habitat – biotic characteristics, habitat – abiotic characteristics, pollution exposure, and benefit to humans. Below are the sensitivity clusters discussed for the environmental sensitivity field, along with the suggested indicators for each cluster:

1 Biodiversity

This cluster assesses an ecosystem's sensitivity to climate change and characterizes its negative impacts on biodiversity.

The indicators proposed for this cluster are as follows:

a. Species richness
b. Species loss
c. Key species loss
d. Species proximity to the thermal threshold
e. Risk of ecosystem collapse
f. Ecosystem value

2 Habitat – Biotic Characteristics

This cluster focuses on the sensitivity of habitats to climate change, particularly their biotic characteristics.

The indicators proposed for this cluster are as follows:

a. Habitat sensitivity
b. Habitat diversity
c. Balancing human and ecosystem needs in environmental flow management

3 Habitat – Abiotic Characteristics

This cluster focuses on the sensitivity of habitats to climate change, particularly their abiotic characteristics.

The indicators proposed for this cluster are as follows:

a. Impact on soil characteristics
b. Impact on water characteristics

4 Pollution Exposure

This cluster assesses pressures on habitats and exposures resulting from human activity. The more a species is exposed to pollutants, the greater its sensitivity to climate change.

The indicators proposed for this cluster are as follows:

a. Habitat located downstream from treated wastewater discharge
b. Risk of negative impacts from wastewater discharge
c. Proximity to human activity
d. Proximity to hazardous industrial activity
e. Level of environmental protection of the habitat

5 Benefit to Humans

This cluster evaluates the contribution of a habitat or ecosystem to human well-being. Identifying and characterizing ecosystems' value to humans helps allocate resources for their protection and restoration.

The indicators proposed for this cluster are as follows:

a. Supporting services
b. Regulating and monitoring services
c. Provisioning services
d. Cultural services

Part 1: Introductions

[1]

Background

Israel is located in a climate change hotspot, where the impacts are anticipated to be more pronounced[1,2]. Meteorological projections indicate a summer warming of approximately 2.2 degrees Celsius by 2050, compared to the average temperatures of 1961-1990; a reduction in precipitation by the end of the century by an average rate of 15%-25%; increased frequency and intensity of heat loads[3]; increased frequency of intense rain events leading to flooding[4]; and a sea level rise at a rate exceeding 4 mm per year[5,6].

The impacts of climate change are not evenly distributed, disproportionately affecting vulnerable populations. Without adequate adaptation efforts, climate change is expected to exacerbate social disparities based on economic, gender, ethnic, and health factors, and worsen inequality[7,8,9,10,11,12,13]. In Israel, as in other countries, vulnerable populations in urban areas often lack shade, lack public open spaces, and face increased air pollution and poor infrastructure[14]. Energy poverty further exposes these populations to heatwaves. Significant disparities exist between Jewish and Arab communities in areas like wastewater treatment, water quality, transportation access, air quality[15],

1. The Ministry of Environmental Protection. 2019. Israel's Adaptation Plan to Climate Change. 1st Report. Submitted to the Government of Israel by the Climate Adaptation Administration in implementation of Government Resolution No. 4079 on Israel's adaptation to climate change. In Hebrew.
2. Hochman A, et al. 2018. High-resolution projection of climate change and extremity over Israel using COSMO–CLM. International Journal of Climatology 38 (14): 5095–5106.
3. Israel Meteorological Service, National Emergency Authority. 2023. Extreme Weather – Heatwaves: Reference Scenario. In Hebrew.
4. Yitzhak Y, et al. 2019. Climate change in Israel – historical trends and future predictions of temperature and precipitation. Research report No. 000075-2019-0804-40000. Israel Meteorological Service. In Hebrew.
5. Kronfeld-Schor N. 2022. Preparation for climate crisis: Sea level rise: Israel must update the predictions and scenarios regarding sea level rise. The Ministry of Environmental Protection. In Hebrew.
6. Lazar A, Biton E, Zask A. 2023. Reference scenarios for climate change: Sea Level Rise. IOLR Report, H04/4/2023. In Hebrew.
7. Ministry of Environmental Protection, Haifa University, Tel Aviv University, Technion, Samuel Neaman Institute. 2013. The climate change information center in Israel: Adaptation to climate change in local authorities. In Hebrew.
8. Benevolenza MA and DeRigne LA. 2019. The impact of climate change and natural disasters on vulnerable populations: A systematic review of literature. Journal of Human Behavior in the Social Environment 29 (2): 266–281.
9. United Nations Environment Programme. 2020. Emissions Gap Report 2020 – Executive Summary. Nairobi.
10. Agyeman J, et al. 2016. Trends and directions in environmental justice: from inequity to everyday life, community, and just sustainabilities. Annual Review of Environment and Resources 41 (1): 321–340.
11. Brand Levy E. 2021. Vulnerable populations and the climate crisis. Ministry of Welfare and Social Affairs. In Hebrew.
12. Krigel K. 2020. Israel's adaptation to climate change – mapping vulnerable populations. Ministry of Environmental Protection. In Hebrew.
13. Shibli H, Teschner N and Shapira S. 2022. Energy poverty under climate change conditions and its implications on community resilience. Kriot Israeliot. Vol 2. In Hebrew.
14. Central Bureau of Statistics. 2020. Well-being, sustainability and national resilience indicators. In Hebrew.
15. Shmueli D. 2011. Environmental justice in the Israeli context. In: Sustainability: Vision, Values, Implementation (J Bernstein ed.). Heschel Center for Sustainability and Ministry of Environmental Protection. 217-229. In Hebrew.

and public open spaces[16,17]. The more than 30 unrecognized Bedouin villages in the Negev face limited access to power supply, quality healthcare services, and safe employment opportunities[18,19,20].

Moreover, communities' geographic location also influences their sensitivity to climate change. Urban areas are vulnerable to urban heatwaves[21]; households located in proximity to forested areas are vulnerable to forest fires[22]; while coastal cities are vulnerable to flooding events, as well as to rising sea-levels[23,24].

Various sectors will be affected differently by climate change. Agriculture will see reduced crop yields and livestock production, declining fish stocks, and increased pest populations. The energy sector will face higher electricity demands as well as grid disruptions during extreme weather. Insurance companies may refuse coverage for structures in vulnerable areas. The labor market will be affected by changing conditions. Reduced water availability will increase pressure on potable water sources. Moreover, the impacts on one sector are likely to have indirect effects on other sectors.

Finally, ecosystems are crucial for community adaptation and preparedness, but face pressures from both climate change and development, compromising their ability to provide essential services. These pressures are expected to vary between different areas.

Climate vulnerability is thus a complex issue with several key dimensions. The impact of climate change is not determined by the mere exposure to climate fluctuations, but also by the sensitivity of the population in the exposed region, as well as by the capacity of communities, institutions, and services to prepare and adapt to these changes.

While many current adaptation efforts focus on physically preparing for expected climate conditions, these actions alone are insufficient to reduce vulnerability. It is crucial to also reduce the sensitivity of communities and households and enhance the preparedness of communities, institutions, and services. Given the multi-dimensional nature of climate vulnerability, building resilience requires data-driven analyses of the social, economic, political, and environmental aspects of different regions and

16. Halász A. 2022. Physical infrastructures for inclusive growth: Can accessibility gaps in physical infrastructures be diminished to ensure inclusive and sustainable growth?. Yesodot. In Hebrew.
17. Lapidot N, Vasl A and Partush A. 2019. Implementation of SDG11 in Israel: challenges and future prospects. Ministry of Housing and Construction. In Hebrew.
18. Shapira S, Shibli H and Teschner N. 2021. Energy insecurity and community resilience: the experiences of Bedouins in Southern Israel. Environmental Science and Policy 124: 135–143.
19. Tubi A and Feitelson E. 2019. Changing drought vulnerabilities of marginalized resource-dependent groups: a long-term perspective of Israel's Negev Bedouin. Regional Environmental Change 19: 477–487.
20. Shibli H, Aharonson-Daniel L and Feder-Bubis P. 2021. Perceptions about the accessibility of healthcare services among ethnic minority women: a qualitative study among Arab Bedouins in Israel. International Journal for Equity in Health 20: 117.
21. Bar R and Sharon O. 2019. Cities in an era of climate change – vulnerability and adaptation. Ecology and Environment 10 (4): 84–89. In Hebrew.
22. Levy S. 2020. Open area fires in Israel. Fire and Rescue Authority. In Hebrew.
23. For example, in the event of sea-level rise, the urban drainage system in nearby localities is expected to be affected, reducing the flow gradient and causing a backward flow of runoff water.
24. Kronfeld-Schor N. 2022. Preparation for climate crisis: Sea level rise: Israel must update the predictions and scenarios regarding sea level rise. The Ministry of Environmental Protection. In Hebrew.

their systems. Such analyses inform resource allocation, ensuring the equitable distribution of climate change risks and adaptation benefits.

To address this need, the Office of the Chief Scientist at the Ministry of Environmental Protection is leading an initiative to map climate vulnerability in Israel[25]. The goal is to provide a professional basis for planning adaptation actions and formalize a comprehensive government policy in response to anticipated climate trends. The vulnerability map will provide relevant spatial data on all aspects of climate vulnerability to a diverse audience, including local and national decision-makers, emergency and rescue organizations, and business professionals.

The expert committee on developing a climate vulnerability index lays the methodological groundwork for this map. This effort serves as an initial step in the government's preparation for climate change and its associated risks.

The impacts of climate change are not evenly distributed. The impact of climate change is not determined by the mere exposure to climate fluctuations, but also by the sensitivity of the population in the exposed region, as well as by the capacity of communities, institutions, and services to prepare and adapt to these changes.

25. Tsalyuk M, et al. 2022. Blueprint for mapping climate change risks in Israel. In Hebrew.

[2]

Climate Vulnerability Maps

Climate vulnerability maps are graphical representations of exposure data, sensitivity, and adaptation capacity. They are essential tools for decision-makers. These maps can be global, comparing countries, or they can provide a comparative outlook on neighborhoods within a city. Some maps focus on single exposure factors like heatwaves or forest fires, while others present multiple factors. Some maps concentrate on distinct sensitivity fields, such as public health, economy, or biodiversity, while others depict multiple fields at once. Additionally, some maps show the current state, while others forecast future trends.

A vulnerability map is not a one-size-fits-all product but should be developed based on defined objectives, specific needs, and existing limitations.

In 2017, the Ministry for Economic Development and Cooperation of the German Government published one of the most comprehensive guides for conducting a vulnerability assessment[26]. The authors emphasize that reducing communities' vulnerability to climate change hinges on a detailed understanding of vulnerability characteristics across different regions. A vulnerability assessment serves several objectives, including identifying climate change impacts and prioritizing adaptation alternatives during the planning phase. Conducting standard assessments over time creates tools for monitoring and evaluating the effectiveness of adaptation measures. This helps determine if vulnerability has decreased due to these measures. A vulnerability index that includes environmental, social, economic, and health components allows decision-makers to evaluate vulnerability in specific regions and address structural limitations effectively.

A climate vulnerability map is a graphical representation of exposure data, sensitivity, and adaptation capacity. It is an essential tool for decision-makers. It is not a one-size-fits-all product but should be developed based on defined objectives, specific needs, and existing limitations.

Here are a few examples of vulnerability maps that can inspire climate impact mapping efforts:

Neighborhoods at-Risk is a tool developed by the Headwater Economics Research Institute. The map and underlying index enable users to evaluate climate vulnerability in each neighborhood across the US. It allows selection from a wide variety of exposure and sensitivity indices, including the neighborhood's age distribution, presence of flood-prone assets in the region, proportion of residents with no medical insurance and more.

The Country Index of the University of Notre-Dame allows for comparisons of vulnerability levels and characteristics among countries,

26. Fritzsche K, et al. 2014. The Vulnerability Sourcebook: Concept and guidelines for standardised vulnerability assessments. German Federal Ministry for Economic Cooperation and Development.

aiming to assist governments, businesses, and investors in prioritizing investments effectively. The index comprises two main components: the Vulnerability Index, which measures a country's levels of exposure, sensitivity, and adaptive capacity across six life-supporting sectors (food, water, health, ecosystem services, human habitat, and infrastructure). And the Readiness Index, which measures a country's ability to leverage investments to adaptation actions through an analysis of three main measures (economic readiness, governance readiness, and social readiness).

London Climate Risk Maps, is the result of a collaboration between the City of London and Bloomberg Associates, and enables users to analyze vulnerability to flooding, heatwaves, or both, in each of Greater London's 4,800 statistical areas. Users can select from various sensitivity indices, including proportion of low-income and ethnic minority households. This map stands out for allowing users to compare layers of distinct vulnerability indices with the flooding and heatwave risk maps of the entire city. The tool also provides access to specific metrics of each grid on the map in exceptionally high resolution.


Photo by Chaim Carmon

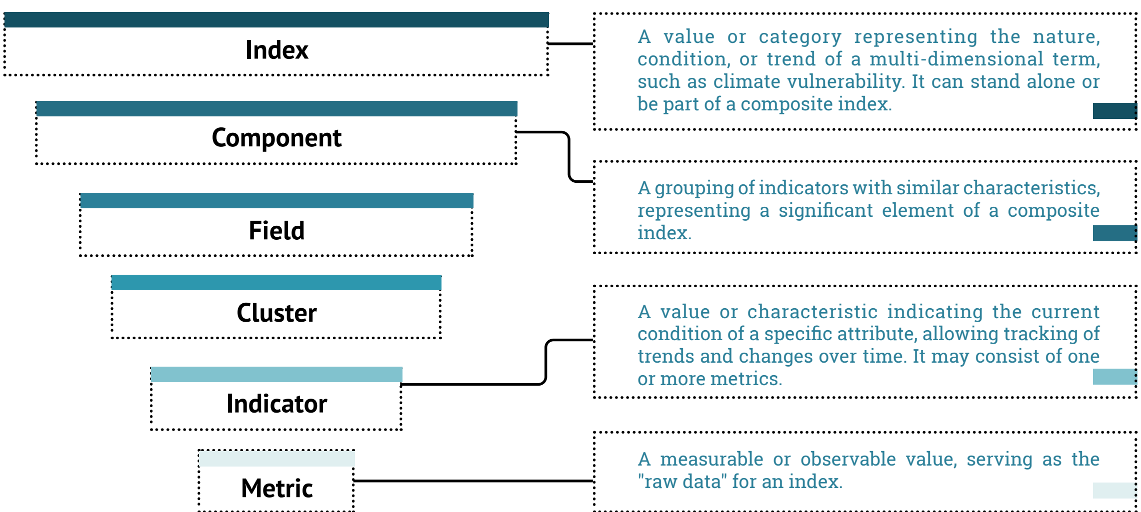
[3]

Climate Vulnerability Index

A Climate Vulnerability Index is a methodological tool, used to select relevant and reliable data from a vast array of available data, weigh the selected data according to a carefully designed key, and process them into standardized values for comparison. This process enables the visual presentation of the data.

A vulnerability index typically comprises three components: exposure, adaptive capacity, and sensitivity. Each component consists of indicators that can be grouped into several clusters and fields. For example, in the environmental sensitivity field, indicators may include factors such as the proportion of respiratory diseases, age distribution, or the proportion of individuals lacking comprehensive medical insurance. In the socio-economic sensitivity field, indicators may include factors such as income level, proportion of single-parent families, or real estate value. In the environmental sensitivity field, indicators may include factors such as species diversity, proportion of open spaces, or habitat continuity. In the field of sensitivity relating to operational continuity, indicators may include factors such as water and energy storage capacity or susceptibility of agricultural yields to interruptions in water supply. Assigning weights to all indicators produces a value that represents the sensitivity level of a particular area to climate change.

Selecting the indicators that will form the index is the initial and crucial step in designing the sensitivity map as a cohesive unit. The expert committee's goal is to establish a scientific and professional infrastructure for developing a climate vulnerability index. Characterizing the indicators for the Israeli climate vulnerability index is essentially the methodological tool that will underpin the national climate vulnerability map.



[4]

Vulnerability Index Components

The following terms have diverse definitions in scientific literature[27,28,29,30,31]. The choice of a specific definition can significantly impact the outcomes of a research project and its reflection of reality. The definitions provided here are not the result of exhaustive methodological work, but rather a synthesis of pertinent definitions from the literature that align with the needs of this project. These definitions aim to establish a common language among those involved in constructing the evaluation methodology and its implementation.

Vulnerability

Vulnerability is the extent to which a system is expected to be negatively impacted by climate change, including extreme events. Vulnerability level is derived from three factors: exposure level, sensitivity level, and adaptive capacity.

Adaptive Capacity

Adaptive Capacity is the system's capacity to adapt to climate change, mitigate its negative impacts, or recover from damages incurred. It includes the abilities, resources, and institutions that enable effective adaptation efforts.

Exposure

Exposure refers to the nature, intensity, or rate of climate change and fluctuations, including factors like temperature levels, precipitation quantities, and extreme events such as intense rains, heatwaves, and prolonged drought periods.

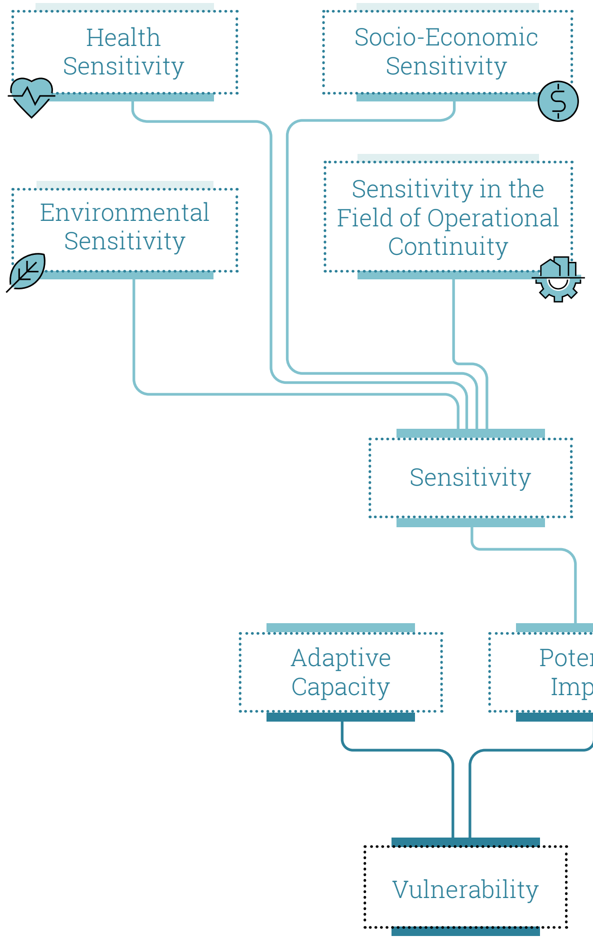
Sensitivity

Sensitivity is the expected degree of impact, whether negative or positive, of any exposure factor on social, economic, or environmental systems. It is influenced by physical factors like topography and soil permeation, human activity such as stormwater runoff management systems and urban shade distribution, and social factors like population density, morbidity, or socio-economic resilience.

27. Summers JK, et al. 2017. Development of a Climate Resilience Screening Index (CRSI): An Assessment of Resilience to Acute Meteorological Events and Selected Natural Hazards. US Environmental Protection Agency.
28. IPCC. 2022. Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Pörtner HO, et al. eds.). Cambridge University Press. Cambridge University Press, 3056 pp.
29. Fritzsche K, et al. 2014. The Vulnerability Sourcebook: Concept and guidelines for standardised vulnerability assessments. German Federal Ministry for Economic Cooperation and Development.
30. Bizikova L, et al. 2009. VIA Module Vulnerability and Climate Change Impact Assessments for Adaptation.
31. Estoque RC, Ishtiaque A, Parajuli J, et al. 2023. Has the IPCC's revised vulnerability concept been well adopted?. Ambio 52: 376–389.

Impact Chain

The concept of vulnerability can be understood through an analytical tool known as the impact chain. This tool defines vulnerability as the final link in a chain consisting of elements of sensitivity, exposure, and adaptive capacity. Each of these components is uniquely influenced by a range of environmental, economic, and social variables, and their weighting is what ultimately enables the overall vulnerability assessment.



[5]

Discussions of the Expert Committee

On 30 April 2023, the expert committee for the development of the climate vulnerability index convened at the Steinhardt Museum of Natural History in Tel Aviv. This was a joint initiative of the Israel Society of Ecology and Environmental Sciences and the Chief Scientist in the Ministry of Environmental Protection, supported by the Heinrich Böll Foundation. The committee included experts from various research institutes, government authorities, and civil society organizations, as well as selected representatives from the defense system, local government, and industry. More than 100 experts participated in the discussions, which were divided into five roundtables. Each roundtable held a three-hour discussion, led by specialist experts in their respective fields, who volunteered for this task. These experts also helped formulate research questions to guide the discussions.

The discussions aimed to address two main objectives. Firstly, experts were asked to identify challenges, limitations, and opportunities in establishing a sensitivity index for each field. Secondly, experts were tasked with creating a list of potential and relevant indicators for each field, using a predefined set of criteria developed by the committee staff and leading specialist experts. A preparatory background document was created by the committee staff and distributed to all participants ahead of the discussions to align the participants, update them on relevant developments, create a common technical language, and clarify the committee's objectives and tasks.

In the discussion focusing on socio-economic sensitivity, 20 experts participated, representing a wide array of sectors: researchers from academic and civil institutes, industry, civil society, as well as representatives from the Central Bureau of Statistics, the Ministry of Welfare, the Ministry of Environmental Protection, the Ministry of Finance, and finally, local government representatives. The discussion was facilitated by Gal Tamir from the Ministry of Environmental Protection. The three-hour discussion extensively covered all the possible sensitivity factors pertaining to the socio-economic field, as will be described below. As the discussion reached its conclusion, 22 indicators were selected for this field, organized into four clusters: social sensitivity, economic-financial sensitivity at the household level, economic-financial sensitivity at the economy level, and socio-economic sensitivity at the local authority level.

In the discussion focusing on the field of operational continuity, 21 experts participated, representing a wide array of sectors: researchers from the fields of urban sustainability, climate planning, and emergency management, alongside representatives from the Electricity Authority, the Water Authority, the Ministry of Energy, the Ministry of Transportation, the Fire and Rescue Authority, the IDF, the Ministry of Agriculture, and more, as well as representatives of local government. The discussion was facilitated by Dr. Ori Sharon from Bar-Ilan University. The three-hour discussion extensively covered all possible sensitivity factors pertaining to this field. As the discussion reached its conclusion, 63 indicators were selected for this field, which can be organized into nine clusters: water supply, electricity supply, mobility and transport, food systems, fire and rescue services, wastewater management, communication systems, the built environment, and susceptibility to flood events.

In the discussion focusing on health sensitivity, 16 experts from the fields of public health and environmental health participated, including representatives from academic and civil society research institutes, and from the government, such as the Ministry of Health, the Ministry of Labor, and the Central Bureau of Statistics. The discussion was facilitated by Dr. Ronit Ratzon from the Ministry of Health. The three-hour discussion extensively covered all sensitivity factors relevant to the health field. As the discussion reached its conclusion, 25 indicators were selected for this field, organized into six clusters: age distribution, medical conditions, fertility and birth, access to health services, pollution exposure, and occupation.

In the discussion focusing on environmental sensitivity, 17 experts participated, including representatives from the Ministry of Environmental Protection, the Central Bureau of Statistics, and academic and civil society institutions. The discussion was facilitated by Dr. Amiel Vasl from the Ministry of Environmental Protection. The three-hour discussion extensively covered all relevant sensitivity factors. As the discussion reached its conclusion, 20 indicators were selected for this field, organized into five clusters: biodiversity, habitat – biotic characteristics, habitat – abiotic characteristics, pollution exposure, and benefit to humans.

In the discussions focusing on integrating the various sensitivity fields and the vulnerability components constituting the index, 23 experts participated. They included academic researchers from fields such as earth sciences, geography, urban planning, local sustainability, environmental health, law, and public policy. The experts also represented governmental divisions such as the Central Bureau of Statistics and Survey of Israel, as well as civil society representatives, research institutes, industry, and local government. The discussion was facilitated by Omri Carmon from Ben-Gurion University.

[6]

Indicators Selection Process

Indicators are the fundamental building blocks of vulnerability indices, shaping their validity, reliability, and effectiveness. The selection process involves condensing many social, economic, and environmental topics into key indicators. This process should be informed and iterative, involving a broad range of stakeholders and experts through sharing and consultation. **In our expert committee, our task was to conduct this process and formulate a recommendation on the indicators for the vulnerability index**.

We studied numerous vulnerability indices from around the world, accompanied by technical documents specifying the selection process of the indicators[32]. Drawing from these publications and professional guidelines[33], we delineated the most important considerations for selecting indicators to optimally serve the vulnerability index.

In characterizing the indicators for the national vulnerability index, we were guided by several key considerations:

- Specificity: Indicators should be as specific as possible, ensuring clarity about the data needed for measurement.
- Representativeness: Indicators should reliably represent essential characteristics of a single vulnerability component, demonstrating any change in indicator value as indicative of a positive or negative development in vulnerability level.
- Avoidance of redundancy: The selection process should avoid choosing similar indicators for the same vulnerability component.
- Data availability: Selected indicators should reflect reliable, readily available, and relevant data.
- Geographic representation: Selected indicators should reflect data that covers a sufficient geographic range and represents each region in the country.
- Temporal consistency: Selected indicators should reflect data that is expected to be current and available both presently and in the future.
- Stakeholder agreement: Indicators should represent a wide agreement among all stakeholders.

Importantly, the characteristics of a climate vulnerability index are inherently dependent on time and context: what applies to one geographical region may not be directly applicable to another. Each context demands specific adjustments. The goal of the expert committee selection process is to identify and define the indicators that will form the basis of the national climate vulnerability report, drawing on the wealth of global knowledge and experience available.

32. Department for Communities and Local Government. 2011. The English Indices of Deprivation 2010: Neighbourhoods Statistical Release.
33. Fritzsche K, et al. 2014. The Vulnerability Sourcebook: Concept and guidelines for standardised vulnerability assessments. German Federal Ministry for Economic Cooperation and Development.


Photo by Nicole Baster on Unsplash

[7]

A Literature Review – Vulnerability Indices from a Global Perspective

Background

In the past two decades, governments, cities, non-governmental organizations, and supranational bodies have developed a wide array of climate vulnerability indices. These indices serve as crucial tools for decision makers, offering comprehensive assessments of the vulnerability levels of populations and systems considering anticipated climate change. This chapter aims to review several examples of climate change indices. One of the key takeaways from these studies and initiatives is the recognition of the substantial resources and expertise invested in developing well-founded methodologies for assessing climate vulnerability. This highlights the importance of leveraging existing knowledge and methodologies rather than starting from scratch.

Global Perspective on Vulnerability: UN Initiatives for Climate Vulnerability Assessment

A report by the UN environmental agency provides guidance on integrating climate change and vulnerability considerations into countries' environmental status reports[34]. It outlines two approaches: a comprehensive one and a focused approach on specific objectives like agriculture or water supply. Vulnerability, defined in the report, is a system's potential to be affected by climate change, determined by exposure, sensitivity, and adaptive capacity. Sensitivity relates to socio-economic development, while adaptive capacity depends on resource access and social systems' effectiveness. Ecological systems are vital for maintaining a society's ability to prepare for and adapt to change. However, pressures from climate change and development significantly impede these essential ecosystem services.

In 2012, the Intergovernmental Panel on Climate Change (IPCC) published a special report on managing the risks of extreme events and disasters to advance climate change adaptation[35]. This report reviews scientific literature on the relationship between climate change and extreme weather events, as well as their social implications. It examines how climate, environmental, and human factors interact to potentially cause damage, provides options for disaster risk management, and highlights the crucial role of social systems in adaptation efforts. The report focuses on disaster risk, particularly emphasizing challenges more relevant to developing countries. In this context, *risk* is understood as the result of *exposure, vulnerability*, and *extreme events*.

34. Bizikova L, et al. 2009. VIA Module Vulnerability and Climate Change Impact Assessments for Adaptation.

35. IPCC. 2012. Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (Field CB, et al. [eds.]). A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA.

The report highlights several common and important insights. Among those is the understanding that the severity of disasters depends on the interplay of exposure and vulnerability, which are influenced by various factors such as socio-economic status, social marginality, and the quality of adaptation systems. Mitigating the impacts of disasters therefore requires reducing both exposure and vulnerability; dynamic factors shaped by economic, social, geographic, demographic, cultural, institutional, and environmental conditions. Inequality poses a significant challenge to adaptation efforts at local and national levels. Moreover, climate events exacerbate vulnerability by diminishing resilience, preparedness, and adaptive capacity, thus creating a feedback loop with social vulnerability. Effective adaptation strategies are those that not only provide economic and social benefits – but also reduce vulnerability over the long term.

The UNDP is promoting an initiative to develop a multi-dimensional vulnerability index (MVI), primarily for small island countries but with broader applicability[36]. According to the UNDP report, while numerous climate vulnerability indices have been developed over the past 25 years, the academic discussion has only recently begun emphasizing the importance of reducing exposure to uncertainty and risks to improve overall well-being. While the MVI may not directly apply to Israel, its detailed methodology for vulnerability assessment is valuable. The index consists of four components with nearly identical variability, allowing for the estimation of vulnerability sources and identification of main indicators within each component.

Regional Climate Vulnerability Assessment

The European Union

The European Union's CLIMASAVE initiative has developed a comprehensive vulnerability index that considers social, economic, political, cultural, and environmental factors[37]. The index emphasizes the need for indicators that reflect this diversity while remaining easy to quantify and apply. It highlights the importance of accurately estimating socio-economic trends for a reliable analysis of climate change risks. CLIMASAVE distinguishes between two interpretations of vulnerability: the extent of damage caused by climate change (end-point interpretation) and the reduction of socio-economic factors contributing to climate change risk (start-point interpretation). The initiative aims to create a platform where both interpretations can coexist. CLIMASAVE also addresses the common focus of climate vulnerability studies on specific sectors (e.g., agriculture, food, water) by aiming to develop evaluation tools that consider multiple sectors and their interdependencies. Additionally, in terms of adaptive capacity, CLIMASAVE focuses on indicators that reflect society's resources to deal with crises, including natural, human, social, financial, and manufactured capital. The choice of indicators may vary based on the scale of analysis, with macroanalysis favoring indicators such as GDP and microanalysis favoring indicators such as income level and savings value in specific populations.

36. Assa J and Meddeb R. 2021. Towards a multidimensional vulnerability index. United Nations Development Programme.
37. Dunford R et al. 2013. Report on assessment of vulnerability across Europe and the identification of vulnerability hotspots. The CLIMSAVE Project.

Latin America

In 2014, the Central Development Bank of Latin America (CAF) published a study on the Climate Change Vulnerability Index (CCVI) for the Latin America and Caribbean region[38]. The study aimed to identify the physical impacts of climate change, population sensitivity, and institutional capacity. The CCVI assesses exposure to climate change and extreme events, sensitivity, and adaptive capacity, with each component contributing to the overall vulnerability score. The index is composed of three components: exposure (50%), sensitivity (25%), and adaptive capacity (25%). Exposure represents the level of threat posed by climate change, while sensitivity reflects the interaction between human populations and natural systems. Adaptive capacity measures a country's ability to adapt to and even benefit from climate change. Factors influencing adaptive capacity include the strength of the economy, the stability and efficiency of the government, the accessibility of data, the country's capacity for technological innovation, available natural resources, and the level of economic dependency on climate-sensitive operations like agriculture. Importantly, adaptive capacity can be expressed by reducing the sensitivity of the population or by developing mitigating measures to reduce the threat itself. The CCVI aims to provide a comprehensive framework for assessing climate change vulnerability, helping decision-makers develop effective strategies for climate adaptation and resilience building in the region.

Vulnerability Evaluation at the State Level

The United States

A publication by the US Environmental Protection Agency from 2017 outlines the Climate Resilience Screening Index (CRSI) for estimating resilience to extreme climate events and natural disasters across the United States[39]. The CRSI aims to create climate change-resilient environments that ensure the continued prosperity of communities and regions while preserving their social and natural environments. The index consists of five components (risk, governance, society, built environment, natural environment) and includes 20 indicators calculated by 117 metrics. Each indicator is explained in the report, detailing its significance, rationale for inclusion, and quantification metrics. The selection of metrics was based on a literature review and expert opinions, focusing on relevance in measuring climate events and weather influences, contribution to evaluating relationships between natural and built environments, and accuracy in representing indicators. All candidate metrics were ranked relative to their suitability, and final selection was based on this assessment.

United Kingdom

Since 2000, the United Kingdom has published the English Indices of Social Deprivation. These indices provide high-resolution deprivation indicators for small areas with approximately 1500 residents

38. Development Bank of Latin America. 2014. Vulnerability Index to climate change in the Latin American and Caribbean Region.
39. Summers JK, et al. 2017. Development of a Climate Resilience Screening Index (CRSI): An Assessment of Resilience to Acute Meteorological Events and Selected Natural Hazards. US Environmental Protection Agency.

(Lower-layer Super Output Areas – LSOAs)[40]. These indices measure social deprivation, which refers to a relative deficiency in resources and means, differentiating it from poverty, which is primarily defined by a lack of financial resources. The English deprivation indices consist of seven components: Income, Employment, Education, Skills and Training, Health and Disability, Crime, Barriers to Housing and Services, and Living Environment. For example, indicators under the Living Environment component include the number of houses with central heating, while the Income component includes the number of asylum seekers receiving assistance.

The selection of indicators for the indices was guided by five central principles: specificity and relevance to the essential characteristics of the deprivation component, regular updates, statistical basis, consistent availability across all regions, and accessibility in desired measurement scales. Each index stands alone, but when weighted together with differential factors ranging from 9.3% to 22.5% for each indicator, they contribute to the creation of the final Index of Multiple Deprivation (IMD). The IMD is visually represented in maps that show the ranking and categorization of neighborhoods according to the deprivation index. These maps are available for each country in the United Kingdom: England, Scotland, Wales, and Northern Ireland.

In April 2022, a report by the British Environment Agency substantiates the increased vulnerability to flood risks among deprived communities[41]. Identifying a direct link between exposure to flood risk and patterns of social inequality, the study also found that investment in the bottom two deciles of the deprivation index has resulted in a reduction in vulnerability to flood risk.

Vulnerability Evaluation at the Local Government Level

In 2022, Bloomberg Associates and the City of London collaborated to publish a comprehensive Climate Risk Map for Greater London[42]. This project aims to support sustainability initiatives by identifying areas and communities at the highest risk of climate change impacts. The underlying assumption is that climate change will not affect everyone equally; vulnerable populations will experience more severe damage from heatwaves and flooding. The map will help policymakers make informed resource-allocation decisions. Data for the map include datasets from the population census and privately licensed and commercial datasets obtained by the City of London. The map focuses on three risk categories, with 13 metrics in the overall risk category, including factors such as the proportion of children under 5, adults over 75, non-English proficient residents, income deprivation, social renters, ethnic minority populations, average surface temperature, exposure to flood events, air pollution levels, green/blue land cover, and access to public spaces.

40. Ministry of Housing, Communities & Local Government. 2019. The English Indices of Deprivation 2019 (IoD2019). Statistical Release.
41. UK Environment Agency. 2022. Social deprivation and the likelihood of flooding: Chief Scientist's Group report. Version 2.1.
42. Bloomberg Associates. 2022. London Climate Risk. Spatial Analysis of Climate Risk Across Greater London: Methodology Report.

Part 2:
Findings of the Expert Committee

4 fields

24 clusters

[• • • •]

[• • • • • • • • •]

[• • • • • •]

[• • • • •]

Chapter 1: Socio-Economic Sensitivity

Background

The study of climate vulnerability hinges on understanding socio-economic sensitivity, which forms the basis for the vulnerability of different populations to climate change impacts. Vulnerable groups often face increased sensitivity due to poor infrastructure, limited social and financial safety nets, inadequate emergency preparedness, higher risks of physical and psychiatric health issues, and more[43,44]. For instance, affluent families might afford better protection against climate impacts, like well-constructed homes and occupations that minimize exposure to adverse weather. In contrast, marginalized groups often live in areas and housing more prone to natural disasters, work in jobs with prolonged outdoor exposure, and rely heavily on public transportation. Moreover, these communities may have limited access to quality healthcare, exacerbating the long-term effects of climate change[45]. Insurance companies may also refuse coverage for municipalities and structures in vulnerable areas. Additionally, vulnerable populations may not receive adequate financial assistance following disasters, and their ability to influence decisions to prevent or mitigate climate-related damages is often constrained[46,47].

Twenty experts participated in the discussion on socio-economic sensitivity, representing a wide array of sectors, including researchers from academic institutes, industry professionals, civil society representatives, and government officials from the Central Bureau of Statistics, the Ministry of Welfare, the Ministry of Environmental Protection, the Ministry of Finance, and local government representatives. The discussion was facilitated by Gal Tamir from the Ministry of Environmental Protection. The three-hour discussion thoroughly examined sensitivity factors in the socio-economic field. As a result, 22 indicators were selected and organized into four clusters: social sensitivity, economic-financial sensitivity at the household level, economic-financial sensitivity at the economy level and socio-economic sensitivity at the local authority level.

43. Fritzsche K, et al. 2014. The Vulnerability Sourcebook: Concept and guidelines for standardised vulnerability assessments. German Federal Ministry for Economic Cooperation and Development.
44. Benevolenza MA and DeRigne LA. 2019. The impact of climate change and natural disasters on vulnerable populations: A systematic review of literature. Journal of Human Behavior in the Social Environment 29 (2): 266–281.
45. Kiang K. 2013. Predicted increase in need for comprehensive refugee/migrant health services as climate change provokes further population displacement. Journal of Paediatrics and Child Health 49 (2): 159–160.
46. Tate E and Emrich C. 2021. Assessing social equity in disasters. Eos (Washington, DC): 102.
47. Mohai P and Bryant B. 1991. Race, Poverty & the Distribution of Environmental Hazards: Reviewing the Evidence. Race, Poverty & the Environment 2 (3/4): 3–27.

From the Literature

Findings from studies worldwide support the claim that deprived communities are more vulnerable to climate change impacts. In Britain, a report by the Chief Scientist of the Governmental Environment Agency in April 2022 found that residents of deprived areas face higher flood risks than those in more privileged areas. This aligns with the findings of a detailed evaluation report from 2017[48,49]. Furthermore, GIS-based mapping in Britain illustrates how social vulnerability varies across neighborhoods in response to climate change impacts[50]. Floods are not the only exposure factor for vulnerable communities, as heatwaves also pose significant risks. For instance, a 1995 heatwave in Chicago led to the deaths of 1200 residents, most of whom were elderly, poor, and/or non-white individuals[51]. Similarly, a 2021 heatwave in British Columbia, Canada, resulted in 619 deaths; of those, 67% were aged over 70 years old, 56% were living alone, and 61% were residing in low-income neighborhoods[52].

Minority groups are particularly exposed to the impacts of climate change[53,54]. This finding is evident in Israel, where significant disparities exist between Jewish and Arab communities[55]. These disparities are observed in areas such as wastewater management[56], water quality, access to public transportation[57] and air quality[58]. Additionally, Arab communities face a relative shortage of open public spaces[59], which are essential for mitigating the adverse effects of climate change. These spaces facilitate water permeation and the delay of runoff water, help cool ground surfaces, and contribute to the absorption of pollutants[60].

48. Environment Agency. 2022. Social deprivation and the likelihood of flooding.
49. Joseph Rowntree Foundation, Climate Change and Communities Programme. 2017. Present and future flood vulnerability, risk and disadvantage: A UK assessment.
50. Lindley S, et al. 2011. Climate change, justice and vulnerability: What makes people more or less vulnerable to the impacts of climate change? Joseph Rowntree Foundation Report.
51. Semenza JC, et al. 1996. Heat-related deaths during the July 1995 heat wave in Chicago. New England Journal of Medicine 335 (2): 84–90.
52. Government of Canada. 2022. Canada's National Adaptation Strategy: Building Resilient Communities and a Strong Economy.
53. Environmental Protection Agency. 2021. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency.
54. Berberian AG, et al. 2022. Racial Disparities in Climate Change-Related Health Effects in the United States. Current Environmental Health Reports 9 (3): 451–464.
55. Shmueli D. 2011. Environmental justice in the Israeli context. In: Sustainability: Vision, Values, Implementation (J Bernstein ed.). Heschel Center for Sustainability and the Ministry of Environmental Protection. 217-229. In Hebrew.
56. Neugarten T. 2016. Environmental justice and climate resilience: A recommendation guide for local authorities and governmental bodies in Israel. The Association of Environmental Justice in Israel. In Hebrew.
57. Zussman N, Aviram-Nitzan D and Shoef Kollwitz H. 2021. Israel 2050: A just transition to a low-carbon economy. The Israel Democracy Institute and the Ministry of Environmental Protection. In Hebrew.
58. Levy R. 2016. Environmental justice indicators in Israel: Municipal environmental inequality in the water, air, sewage and public transportation sectors and in open public spaces. The Association of Environmental Justice in Israel. In Hebrew.
59. Halász A. 2022. Physical infrastructures for inclusive growth: Can accessibility gaps in physical infrastructures be diminished to ensure inclusive and sustainable growth?. Yesodot. In Hebrew.
60. Zarchin I and Rofe Y. 2012. The quality of open public spaces – comparing urban neighborhoods in the Negev and the coastal plain. Ecology and Environment 3 (2): 144–153. In Hebrew.

Vulnerable populations are also disproportionately affected by energy poverty compared to more privileged populations[61]. Energy poverty is defined as limited access to energy services necessary for basic household needs, such as heating or cooling[62]. This phenomenon is more prevalent among vulnerable populations, with household income deciles correlating inversely with the percentage of electricity expenditure[63,64,65]. Lower-income households thus often avoid heating or cooling their homes, which can pose direct health risks during extreme weather events[66]. For instance, in 2013, approximately 2.1 million Israelis faced difficulties heating or cooling their homes or had delayed their utility payments due to financial hardships[67]. In 2020, 62% of beneficiaries of the Latet organization in Israel avoided heating or cooling their homes, and 21% reported having no means of heating or cooling[68]. Households which struggle to afford cooling often reside in areas with higher temperatures, compounding their vulnerability. In Tel Aviv, for example, there is a direct association between hotter areas and vulnerable populations, a trend seen in other regions globally[69].

In the European Union, where 41 million residents struggled to keep their houses adequately warm in 2022, several energy poverty indices were developed[70,71,72]. A 2023 index by the European Commission includes nine indicators, such as household income and expenditures, energy consumption, housing prices, and the proportion of people with chronic illnesses[73]. However, in Israel, insufficient data hinders a clear understanding of the extent of this phenomenon[74]. Developing a similar index for Israel could provide a means of gauging and addressing energy poverty; and could additionally serve as an indicator in the national climate vulnerability index.

61. Moore R. 2012. Definitions of fuel poverty: Implications for policy. Energy Policy 49: 19–26.
62. Teschner N. 2023. Energy poverty in Israel. Heinrich-Böll-Stiftung.
63. Garfunkel D, Piso R and Aharon Gutman M. 2022. Can sun rays assist in mitigating inequality in Israel? The socio-economic benefit of solar panels on public housing rooftops. A final report. The Social Hub, Technion. In Hebrew.
64. Shibli H, Teschner N and Shapira S. 2022. Energy poverty under climate change conditions and its implications on community resilience. Kriot Israeliot. Vol 2. In Hebrew.
65. Garfunkel D, Piso R and Aharon Gutman M. 2022. Can sun rays assist in mitigating inequality in Israel? The socio-economic benefit of solar panels on public housing rooftops. A final report. The Social Hub, Technion. In Hebrew.
66. Basagaña X, et al. 2021. Low and high ambient temperatures during pregnancy and birth weight among 624,940 singleton term births in Israel (2010–2014): An investigation of potential windows of susceptibility. Environmental Health Perspectives 129 (10): 1–12.
67. The Central Bureau of Statistics. 2015. The Social Survey 2013. In Hebrew.
68. Latet. 2020. A disturbed reality: The alternative poverty report No. 18. In Hebrew.
69. Lovecchio J, Basic G, and Pawlowski T. 2020. Urban heat, vulnerability, and the public realm: Lessons from Tel Aviv-Yafo and implications for COVID-19 recovery. Smart, Sustainable and Fair Cities 40: 108–136.
70. OPENEXP. 2019. European Energy Poverty Index (EEPI): Assessing Member States' Progress in Alleviating the Domestic and Transport Energy Poverty Nexus.
71. Thema J and Vondung F. 2020 EPOV Indicator Dashboard: Methodology Guidebook. Wuppertal Institut für Klima, Umwelt, Energie GmbH.
72. Gouveia JP, et al. 2019. Energy poverty vulnerability index: A multidimensional tool to identify hotspots for local action. Energy Reports 5: 187 – 201.
73. Gouveia JP, et al. 2023. Energy Poverty National Indicators: Uncovering New Possibilities for Expanded Knowledge. Energy Poverty Advisory Hub, European Commission.
74. Garfunkel D, Piso R and Aharon Gutman M. 2022. Can sun rays assist in mitigating inequality in Israel? The socio-economic benefit of solar panels on public housing rooftops. A final report. The Social Hub, Technion. In Hebrew.

Methodological Considerations

The participants of the expert committee discussion agreed that the statistical areas of the Central Bureau of Statistics (CBS) will serve as the geographic units for the socio-economic sensitivity analysis. CBS presents and analyzes many of its statistical data based on the municipal zoning of cities, local authorities and localities within the regional authorities. However, in larger localities (over 10000 residents), CBS implements a hierarchal internal division method to create statistical, homogenous areas that reflect their complexity and diversity. These areas are designed to be as homogenous as possible but are not necessarily equal in size. Since 1961, the division has been updated before each population census to reflect regional development, new construction, and changes in population size and composition. The main goal of the division is to create small, homogeneous geostatistical units that properly represent the distinct characteristics of each locality. Several principles guide the CBS through this zoning process and delineation of boundaries of statistical areas:

(a) Statistical areas will be limited to the locality's planning boundaries and cover its entire jurisdictional area, without overlap between areas. (b) Each statistical area is as homogenous as possible, and its boundaries are set by criteria such as land uses, period of building, type of structures and demographic considerations. (c) The boundaries of the statistical areas typically follow existing features, such as streets, railroad tracks, fences, streams, etc.; to ease the identification of areas on the map and on the ground. (d) Previously, priority was given to the creation of equally sized statistical areas (ranging between 3000-5000 residents), but since 2022, homogeneity considerations have been prioritized over size considerations in the creation of these areas. (e) In areas where the main land use is industrial, commercial or institutional/public, and not residential, population size or area size will not affect the boundaries of the statistical area. (f) When establishing statistical areas, future development trends are considered, along with existing demographic data of population[75].

For most Arab localities, updated CBS datasets are still unavailable, as many lack specific resident addresses in the administrative data sources. Therefore, the socio-economic index was not calculated for them[76]. In addition, the non-recognition of 30 Bedouin localities in the Negev means a lack of reliable data, increasing the probability of their misrepresentation in the index, or even their complete exclusion[77,78].

The experts discussed various issues related to data sources for the socio-economic sensitivity field. One key concern was the accessibility of sensitive data. For instance, they considered whether it would be feasible to use datasets from local authorities or the National Insurance

75. The Central Bureau of Statistics. 2022. Statistical areas and the process of preparing the statistical areas layer for the 2022 population census. In Hebrew.
76. The Central Bureau of Statistics. 2022. Characterizing geographical units and their classification according to the socio-economic level of the population in 2019. In Hebrew.
77. Almasi O. 2023. Data on the Bedouin population in the Negev. The research and information center of the Knesset. In Hebrew.
78. Negev Coexistence Forum for Civil Equality. 2021. Uncounted: Indigenous Bedouin citizens neglected by the Israeli Central Bureau of Statistics.

Institute and whether these institutions would grant permission. Some data, like that owned by banks and investment houses, is private and may not be accessible, despite its value. Additionally, they debated how to select indicators given the potential difficulty in accessing certain data. Should the index prioritize implementation ability in the near term, focusing on accessible datasets, or aim for an ideal index, hoping that more data will become available in the future? This issue remains unresolved and will be reevaluated as the process progresses.

A population's sensitivity to climate change can be assessed through economic and social factors. The economic approach emphasizes damage to the economy and products, with less focus on residents, magnifying vulnerability in areas like commercial centers and industrial facilities. In contrast, the social approach focuses on damage to residents themselves, especially in deprived areas. The tension between these approaches characterized the debates among experts. Yet despite their differences, both approaches contribute to understanding vulnerability. Indicators for socio-economic sensitivity should balance these perspectives.

Finally, while climate change encompasses both physical risks (like flooding and heatwaves) and transition risks (risks resulting from changes to economic systems), the current report focuses solely on physical risks and their impacts.

Proposed Indicators

The following sensitivity clusters and indicators have been proposed for the socio-economic field:

- **Social Sensitivity**

Social sensitivity refers to individuals' reliance on social capital resources, such as families and communities, to prepare for and cope with climate change impacts, as well as the community's ability to receive assistance from relevant authorities. Vulnerable groups, including elderly people without families[79], unhoused individuals[80,81], international workers[82], undocumented immigrants[83] and single-parent families[84], often have limited access to social capital resources, leading to increased vulnerability. Age distribution is a relevant indicator for this cluster[85]. Studies indicate that children from deprived households, who often

79. Rotem D. 2014. The committee report on practices for coping with loneliness among the elderly. Joint – Eshel Israel. In Hebrew.
80. Santo Y and Berger M. 2014. Mapping the unhoused people in Israel: Final report. Pilat Israel. In Hebrew.
81. Be'eri I and Brilnstein R. 2018. Homelessness in Israel: Conceptualization, measurement, modeling, estimate and policy recommendations. Haifa University, The National Insurance Institute, The Association for Distributive Justice, School of Political Sciences. In Hebrew.
82. Kushnirovich N and Filc D. 2012. Social insurance of work migrants: An international comparison and the situation in Israel. In Hebrew.
83. Rupin Academic Center and Assaf (Aid Organization for Refugees and Asylum Seekers in Israel). 2014. A recommendation report on welfare services for asylum seekers in Israel. In Hebrew.
84. Natanzon R, Gazala I and Porat M. 2017. Single-parent families in Israel. In Hebrew.
85. In this work, age distribution is also listed as a sensitivity indicator in the health field. This duplication is deliberate, as the age distribution indicator highlights distinct and varied sensitivities within each field of sensitivity. This dual sensitivity requires explicit representation in the index. In other words, to comprehensively map all relevant sensitivity factors, indicators related to age should be included in both health and socio-economic sensitivity assessments.

lack structured environments, are more exposed to climate events[86], while elderly people often require social services, the absence of which leads to increased vulnerability. Additionally, the level of education, particularly the absence or existence of high school education, is a key indicator for assessing vulnerability in this context[87].

The socio-economic index of the Central Bureau of Statistics (CBS) is a crucial indicator for assessing vulnerability and social marginality. It comprises four main components: *Demographic Statistics:* This includes the median age in a geographic unit, the dependency ratio of young individuals (0-19) and elderly individuals (over 65), and the proportion of families with four or more children out of the total number of families receiving child support. *Education Statistics:* The includes the average education level of individuals aged 25-54. *Employment and Pension Statistics:* This includes the proportion of individuals aged 25-54 with income from work, the proportion of women aged 25-54 with no income from work, the proportion of individuals exceeding twice the average wage, the proportion of those with work income below the minimum wage, and the proportion of individuals receiving income assurance and supplemental income. *Quality-of-Life Statistics:* The includes average income per capita, average number of vehicles owned among residents aged 17 and above, vehicle license acquisition rate (an estimate of the vehicle value), and average number of days spent abroad[88].

Additional data relevant to the social sensitivity cluster can be found in the Department for Social Services in the Ministry of Welfare. This department conducts continuous mapping of the Ministry's target populations and their needs, delineating the boundaries within which social services operate. The mapping document is valuable for gathering reliable data, formulating policies, planning field interventions, and monitoring policy outcomes. It distinguishes between needs and characteristics: Needs represent problems or difficulties for clients or their environment, indicating a gap between the current situation and the desired state, while background characteristics describe circumstances that may lead to the need but are not focal points for intervention and change.

Climate change is expected to have a greater impact on women than men[89]. In Israel, women are generally more socially and economically disadvantaged, making them more vulnerable[90]. Their increased sensitivity to climate change is also due to limited mobility and employment opportunities, as well as diminished social and economic networks[91]. The more pronounced the

86. United Nations Children's Fund (UNICEF). 2021. The climate crisis is a child rights crisis: Introducing the Children's Climate Risk Index.
87. Centers for Disease Control and Prevention and Agency for Toxic Substances Disease Registry. 2022. Environmental Justice Index.
88. The Central Bureau of Statistics. 2022. Characterizing geographical units and their classification according to the socio-economic level of the population in 2019. In Hebrew.
89. Terry G. 2009. No climate justice without gender justice: an overview of the issues. Gender and Development 17 (1): 5–18.
90. Tzameret H, et al. 2022. The gender index: Gender inequality in Israel 2022. The Van Leer Jerusalem Institute, WIPS and She Knows. In Hebrew.
91. Fritzsche K, et al. 2014. The Vulnerability Sourcebook: Concept and guidelines for standardised vulnerability assessments. German Federal Ministry for Economic Cooperation and Development.

gender inequality, the more vulnerable women become to the impacts of climate change[92]. A state ombudsman report from October 2021 found that extreme weather events, such as heatwaves and droughts, indirectly lead to increased gender-related violence[93]. Additionally, energy poverty disproportionately affects women compared to men. Women who belong to other marginalized social groups, such as those based on ethnicity or nationality, are even more exposed to energy poverty[94].

In the Arab community, the need for households to cover water and energy bills has been identified as a primary reason for girls starting to work while still in high school[95,96]. This phenomenon is driven by economic necessity and underscores the challenges faced by many families in meeting basic needs. Among the various segments of Arab society, the Bedouin community in the Negev stands out for its particularly high levels of deprivation and vulnerability[97]: Approximately 30% of Bedouin community members live in areas that are not connected to the national electricity grid. This lack of access to reliable electricity is a key factor contributing to their heightened exposure to energy poverty compared to other Arab communities in the country[98].

Studies consistently demonstrate that being part of a minority group increases vulnerability[99]. This aspect of vulnerability is typically reflected in vulnerability indices in two main ways: in the United States, minority group affiliation is considered a vulnerability factor in itself[100], while European countries use socio-economic data like income and education, assuming that minority group vulnerability will be inherently captured in these indicators. However, it is worth considering whether there are variables specific to minority groups that are not automatically included in the socio-economic index.

In the case of Arab Israeli society, most Arab localities are ranked in the 4th cluster or lower in the socio-economic index, indicating that the social vulnerability of the Arab community is likely to be reflected in this index[101]. Other sensitivity

92. UNEP, UN Women, DPPA, UNDP. 2020. Gender, Climate & Security: Sustaining inclusive peace on the frontlines of climate change.
93. The State Comptroller and Ombudsman of Israel. 2021. A special report: The actions of the Israeli government and its adaptation to the climate crisis. In Hebrew
94. Krigel K. 2021. Social analysis of the climate crisis: is climate injustice being entrenched at the local level? Ecology and Environment 12 (1). In Hebrew.
95. Krigel K, et al. 2022. A gender perspective to local authorities' adaptation to climate crisis. Kriot Israeliot, Vol. 2. In Hebrew.
96. Athamneh S and Benjamin O. 2021. Education as weapon: poverty and school for Palestinian adolescent girls living in Israel. Gender and Education 33 (2): 235–251.
97. Sikkuy-Aufoq and Arab Center for Alternative Planning. 2022. Planning and regulation in the Arab settlements – a status report. In Hebrew.
98. Shibli H, Teschner N and Shapira S. 2022. Energy poverty under climate change conditions and its implications on community resilience. Kriot Israeliot. Vol 2. In Hebrew.
99. EPA. 2021. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency, EPA 430-R-21-003.
100. Flanagan BE, et al. 2011. A Social Vulnerability Index for Disaster Management. Journal of Homeland Security and Emergency Management 8 (1): Article 3.
101. Haddad Haj-Yahya N, et al. 2022. The Annual statistical report on Arab society in Israel. 2021. Abstract. The Israel Democracy Institute. In Hebrew.

factors relevant to the Arab community, such as access to open public spaces, availability of credit, and consistent electricity supply, are expected to be reflected in other index indicators. Therefore, it might be the case that affiliation to a minority group constitutes a vulnerability factor only insofar as it relates to the spoken language: limited proficiency in the country's predominant language can indeed increase vulnerability to climate change impacts[102,103]. Proficiency in Hebrew is crucial for participation in community activities related to climate adaptation, as well as for accessing welfare and health services[104].

Institutions and bodies that can provide relevant data for the evaluation include the Central Bureau of Statistics, the National Insurance Institute, the Department for Social Services in the Ministry of Welfare, local authorities, and civil society organizations. For instance, civil society organizations can provide data on those without legal status, who are grouped together with international workers under the indicator 'proportion of immigrants'. Moreover, while a gender inequality index does exist in Israel[105], it does not currently measure the extent of inequality according to geographic segmentation. It is essential to promote the adequate allocation of resources and to include this analytical dimension into the index[106].

The indicators proposed for the social sensitivity cluster are as follows:

a. Proportion of single-parent households
b. Proportion of immigrants
c. Proportion of elderly people without family support
d. Proportion of unhoused individuals
e. Education level
f. Degree of gender inequality
g. Age distribution
h. Access to information and knowledge about services
i. Proportion of individuals from minority groups

• Economic-Financial Sensitivity at the Household Level

Numerous methodological guides on developing climate vulnerability indices highlight the importance of considering individual financial sensitivity as a key component in calculating overall vulnerability. For instance, insurance policies serve as a financial safety net in the event of damages from extreme weather events[107,108]. The widespread availability of insurance policies in various sectors enables individuals to seek reimbursement or compensation for specific extreme events, thereby enhancing financial

102. White-Newsome J, et al. 2009. Climate Change, Heat Waves, and Environmental Justice: Advancing Knowledge and Action. Environmental Justice 2 (4): 197–205
103. Nepal V, et al. 2012. Disaster Preparedness of Linguistically Isolated Populations: Practical Issues for Planners. Health Promotion Practice 13 (2): 265–271.
104. McKenzie B, et al. 2022. Technical Documentation for the Environmental Justice Index 2022. US Centers for Disease Control and Prevention.
105. Tzameret H, et al. 2022. The gender index: Gender inequality in Israel 2022. The Van Leer Jerusalem Institute, WIPS and She Knows. In Hebrew.
106. Andrijevic M, et al. 2020. Overcoming gender inequality for climate resilient development. Nature Communications 11 (6261): 1–8.
107. Beck CR and Oliver I. 2019. Effect of Insurance-Related Factors on the Association between Flooding and Mental Health Outcomes. International Journal of Environmental Research and Public Health, 16 (7): 1174.
108. Felsenstein D, Vernik M, and Israeli Y. 2018. Household insurance expenditure as an indicator of urban resilience. International Journal of Disaster Risk Reduction 31: 102–111.

security and reducing economic sensitivity[109]. Similarly, having savings or owning sufficient assets can also provide financial security in similar scenarios. Therefore, the sensitivity indicator for this aspect may encompass access to insurance compensations or savings, or alternatively, access to government restoration funds that can serve as a safety net during extreme climate events[110].

It is also important to note that communities facing a heavier burden of housing costs (due to rental costs, mortgages, or housing prices) are likely to have reduced access to preparedness and adaptation measures in the event of extreme events[111]. This economic burden of housing costs can be represented by the ratio of housing expenses to income level. Moreover, it is crucial to emphasize that homeownership alone does not reliably indicate financial resilience, as the quality of the property (age, size, maintenance condition, etc.) significantly affects its ability to provide economic security. The housing price index from the Central Bureau of Statistics can provide an estimate of the property quality in each area. Additionally, it is worth noting that the sensitivity level of small businesses is higher than that of medium and large businesses. Therefore, relying on a small business as a source of income constitutes a sensitivity factor[112].

Creating a financial resilience index is crucial for measuring individual financial sensitivity. This index should consider factors like insurance access, savings, credit card availability, and ownership of homes, vehicles, property, and businesses. Unlike CBS's socio-economic index, which includes income but not access to capital, this index focuses on broader financial security. Financial institutions might already have similar indices, and regulatory bodies like the Israel Capital Market Authority and the Bank of Israel could oversee data consolidation. Property ownership data can be obtained from the Land Registry, while information on capital accessibility can be sourced from governmental bodies like the Ministry of Welfare and Social Affairs and the National Insurance Institute. CBS also provides relevant data, including the socio-economic index and databases on housing price burdens, and publishes data on average housing prices by living area and number of rooms.

The indicators proposed for the economic-financial sensitivity at the household level cluster are as follows:

a. Socio-economic level
b. Liquid assets
c. Low liquidity assets
d. Degree of insurance coverage
e. Housing cost burden
f. Small business ownership
g. Real estate prices

109. van Valkengoed AM and Steg L. 2019. Meta-analyses of factors motivating climate change adaptation behaviour. Nature Climate Change 9 (2): 158–163.

110. USAID. 2016. Climate Vulnerability Assessment. Technical Report: An Annex to the USAID Climate-Resilient Development Framework.

111. Meltzer R and Schwartz A. 2016. Housing Affordability and Health: Evidence From New York City. Housing Policy Debate 26 (1): 80–104.

112. Lo AY, et al. 2019. Socio-economic conditions and small business vulnerability to climate change impacts in Hong Kong. Climate and Development 11 (10): 930–942.

• Economic-Financial Sensitivity at the Economy Level

According to a report by the Central European Bank, in 2019, extreme climate events resulted in collective financial losses roughly equivalent to 1% of the Gross Domestic Product (GDP) of the entire Eurozone. Projections indicate that this proportion is expected to rise[113]. The report highlights that 18% of southern European companies face significant exposure to heat stress, water scarcity, or forest fires, while 7% of northern European companies face flood risks. Currently, only about a third of weather-related damages are covered by insurance, and this gap is projected to widen. Such findings underscore the need to develop a financial sensitivity index at the level of the economy. This index can include data on the presence of economic engines in a specific geographic area, such as national infrastructure, main commercial, and industrial sites. This inclusion is justified by the potential substantial impacts on both local authorities' revenues and the national product resulting from damage to these sites due to climate events[114].

In evaluating economic sensitivity at the national level, an estimation should be conducted to determine regional concentration of national infrastructures (such as harbors, airports, complex transportation hubs, and vital factories), as well as high-value economic assets and activities (including financial centers and large-scale factories)[115]. The production value of these assets is vital to the economy and the country, and any harm to them could pose a risk of insolvency to insurance companies. Institutions that can provide relevant data for this evaluation include Survey of Israel (for mapping national infrastructures) and the Real Estate Valuation Division at the Ministry of Finance (for property value data). Currently, there is no available index in Israel presenting relevant data on property density and high-economic value activities. Therefore, we propose developing such an index.

The indicators proposed for the economic-financial sensitivity at the economy level cluster are as follows:

a. Concentration of vital infrastructures
b. Density of high value assets and activities

• Socio-Economic Sensitivity at the Local Authority Level

Studies have identified distinct vulnerability to climate change among urban residents[116]. This is especially relevant to Israel, where more than 90% of people reside in urban areas[117]. Certain urban characteristics, such as density and inadequate infrastructure, can enhance the intensity of climate phenomena and expose the urban population to weather-related risks[118]. Vulnerable populations tend to inhabit urban areas that are more exposed to the adverse effects of climate change, characterized by

113. European Central Bank. 2021. Financial Stability Review.
114. Assa J and Meddeb R. 2021. Towards a multidimensional vulnerability index. United Nations Development Programme.
115. E.g., The City of Copenhagen. 2012. Cloudburst Management Plan 2012. October.
116. Dodman D, et al. 2022. Cities, Settlements and Key Infrastructure. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Pörtner HO, et al. eds.). Cambridge University Press, 907–1040.
117. The Central Bureau of Statistics. 2022. Local authorities in Israel 2020. In Hebrew.
118. Bar R and Sharon O. 2019. Cities in the era of climate change – vulnerability and adaptation arenas. Ecology and Environment 10 (4): 84–89. In Hebrew.

lack of shade, increased air pollution, and inadequate infrastructures[119,120,121]. For example, the urban heat island effect, where cities are hotter than surrounding areas, adversely affects residents' comfort, health, and overall energy consumption[122]. Mitigating this phenomenon through higher building standards is challenging in impoverished areas, where building materials are often of reduced quality[123].

Furthermore, a study of tree and shade canopy coverage in Tel Aviv revealed that its northern neighborhoods, characterized by high socio-economic status, have better shading compared to eastern and southern neighborhoods where less privileged populations reside[124]. Dense construction that does not consider climate predictions is expected to increase the risk of floods in cities[125]. Additionally, exposure to extreme weather conditions adversely affects the lives of all residents, especially those who rely on public transport[126]. Many of these sensitivity characteristics are reflected in other indicators in this chapter and others. For example, indicators related to the socio-economic status of households are mentioned in other clusters of the socio-economic field, while indicators related to the sensitivity of infrastructures are mentioned in the sensitivity field of operational continuity. Alongside these, the committee discussions raised several indicators that can indicate the level of economic-financial sensitivity of the local authority itself, and these were granted this separate sensitivity cluster.

Relevant insights for this cluster include the higher sensitivity level of small businesses compared to medium and large ones. The higher the proportion of the municipality's revenue from small businesses, the greater the economic impact during extreme events[127]. Additionally, the proximity to employment and commercial centers, coupled with residents' mobility between them, enhances the authority's resilience. Conversely, distance from these centers, coupled with limited resident access to them, increases the authority's vulnerability to climate events. The peripherality index developed by the Central Bureau of Statistics constitutes an effective indicator for this sensitivity factor.

Discussions highlighted the difference in occupancy patterns between residential and commercial/industrial zones within local authorities, especially during different times of the day. Commercial and industrial areas

119. Brand Levy E. 2021. Vulnerable populations and the climate crisis. Ministry of Welfare and Social Affairs. In Hebrew.
120. Krigel K. 2020. Israel's adaptation to climate change – mapping vulnerable populations. The Ministry of Environmental Protection. In Hebrew.
121. Negev M, Zohar M and Paz S. 2022. Multidimensional hazards, vulnerabilities, and perceived risks regarding climate change and Covid-19 at the city level: An empirical study from Haifa, Israel. Urban Climate 43: 1–13.
122. Erell E. 2016. Should we be worried about the urban heat island? Ecology and Environment 7 (3): 244–250. In Hebrew.
123. Boneh D. 2014. Effect of high-albedo materials on thermal comfort in urban open spaces in warm climates. (master's dissertation). Ben-Gurion University in the Negev. In Hebrew
124. Aleksandrowicz O, et al. 2019. Shade maps and their usage for the preservation and of shade in Tel-Aviv-Yaffo: A summary report. Submitted to the Division of preservation, Tel Aviv-Yaffo municipality. In Hebrew.
125. Egozy R. 2021. Nature based solutions – A toolkit for managing flood risks. Ecology and Environment 12 (3): 49–58. In Hebrew.
126. Makin-Knafo E, et al. 2020. Resilience Accelerator Tel Aviv-Yafo: Urban Heat And The Future Of The Public Realm. Technical Report. Columbia University Center for Resilient Cities and Landscapes.
127. United Nations Development Programme (UNDP) Crisis Prevention and Recovery. 2013. Small Businesses: Impact of Disasters and Building Resilience. Analysing the vulnerability of Micro, Small, and Medium Enterprises to natural hazards and their capacity to act as drivers of community recovery.

are typically busy during the day, but not at night. Incorporating this temporal aspect into the index requires further consideration. The issue of whether population density should be considered a sensitivity factor in a specific authority remained unresolved. Scientific literature generally suggests that population density alone is not a sensitivity factor unless it directly contributes to the vulnerability of the population[128].

The Central Bureau of Statistics is the primary institution that can provide relevant data for this evaluation. Additionally, the Ministry of Economy is expected to have data concerning the proportion of small businesses in the authorities.

The indicators proposed for the cluster of socio-economic sensitivity at the local authority level are as follows:

a. Proportion of small businesses
b. Peripherality index
c. Proportion of residential to commercial and industrial areas
d. Population density

128. Fritzsche K, et al. 2014. The Vulnerability Sourcebook: Concept and guidelines for standardised vulnerability assessments. German Federal Ministry for Economic Cooperation and Development.

Photo by Dalia Nava

Chapter 2: Sensitivity in the Field of Operational Continuity

Background

Sensitivity assessment in the context of operational continuity entails evaluating the ability of authorities to sustain essential services for communities during crises. These services encompass electricity supply, water supply, wastewater disposal, transportation, emergency and rescue services, among others. Each service is uniquely affected by various climate scenarios, with risks differing between warming effects, changes in precipitation, and increased frequency of extreme rain events. Furthermore, risks vary geographically. When assessing authorities' capacity to maintain essential services, two climate change scenarios must be considered: extreme events (e.g., severe heatwaves, floods, forest fires) and chronic exposure to changing climate conditions (e.g., gradual warming, prolonged droughts).

Twenty-one experts participated in the discussion to characterize sensitivity indicators for operational continuity, representing diverse sectors such as urban sustainability, climate planning, emergency management, and various government bodies including the Electricity Authority, Water Authority, Ministry of Energy, Ministry of Transportation, Fire and Rescue Authority, IDF, Ministry of Agriculture, and local government representatives. Dr. Ori Sharon from Bar-Ilan University facilitated the three-hour discussion, which comprehensively covered sensitivity factors. Sixty-three indicators were selected across nine clusters: water supply, electricity supply, mobility and transport, food systems, fire and rescue services, wastewater management, communication systems, built environment, and susceptibility to flood events.

From the Literature

The effects of climate change on various aspects of life in Israel, including operational continuity, are expected to be significant[129]. Agriculture will face reduced crop and livestock yields, declining fish stocks, and increased pest populations. The energy market will see higher electricity demands and power supply disruptions during extreme weather events. Forest fires are projected to occur more frequently, increasing the burden on fire services. Decreased water availability will strain existing freshwater resources. Climate change impacts on neighboring countries could lead to regional instability and increased immigration from those countries. Highlighting the importance of operational continuity, an OECD model applied to Paris found that 35% to

129. The Ministry of Environmental Protection. 2019. Israel's Adaptation Plan to Climate Change. 1st Report. Submitted to the Government of Israel by the Climate Adaptation Administration in implementation of Government Resolution No. 4079 on Israel's adaptation to climate change. In Hebrew.

85% of financial damages incurred by businesses due to urban floods will result not directly from flooding, but from damage to electricity and transportation systems in the city[130].

In 2021, the United States Department of Energy published a vulnerability assessment and resilience planning guidance for its assets and operations nationwide[131]. The guidance aims to assist department sites in prioritizing resilience solutions, considering criteria such as vulnerability severity, expected impact magnitude, restoration costs, potential emission reduction from adaptation, and more. It encourages collaboration between governmental agencies, local councils, regional bodies, and infrastructure companies to establish holistic and effective adaptation plans.

Department sites are advised to prioritize operations and systems such as work teams, site structures, critical equipment, on-site waste management, energy production, communication and ICT systems, transportation infrastructure, water and wastewater treatment, critical material supply chains, on-site ecology, and natural environment preservation. Each site's adaptation plan should assess its exposure to risk factors and the potential impacts on these systems. Additionally, an assessment of the impacts of failures in other systems is required.

Methodological Considerations

The discussion highlighted key insights regarding the challenges and opportunities in risk assessment for operational continuity. A systemic hierarchical prioritization was emphasized, prioritizing critical systems over others. The water supply system was identified as the highest priority, followed by the electricity system, communication, health, food, transportation, wastewater management, flood risk management, and the functioning of green infrastructure.

Many systems crucial for operational continuity during crises depend on the proper functioning of other systems. For instance, water systems rely on the electricity network (or backup systems), wastewater systems depend on the electricity grid, and transportation systems rely on communication systems. Therefore, evaluating the sensitivity of a system involves not only its ability to function in changing climate conditions but also its dependency on other systems, which could be more profoundly impacted.

Further emphasis was placed on the importance of the reference scenarios developed by the National Emergency Authority, which provide a comprehensive assessment of the exposure factors various systems will face[132]. Discussions also highlighted the overlap between structural sensitivity to fires and climate impacts, stemming

130. OECD. 2018. Climate-resilient Infrastructure: OECD Environment Policy Paper No. 14.

131. U.S. Department of Energy, Sustainability Performance Division. 2022. Vulnerability Assessment and Resilience Planning Guidance Version 1.2.

132. The reference scenarios were developed by the Meteorological Service and the National Emergency Agency to enhance adaptation to future extreme weather conditions. These scenarios are derived from the most severe events experienced in the region over the past century and are designed to represent a "reasonably severe" level. According to the updated reference scenarios guide from March 2023, the scenarios cover a range of extreme weather events, including snow and cold events, extreme climate events in three specific areas (Gush-Dan and the coastal plain, the Haifa Bay area, the south and east of Israel), prolonged heatwaves, dust storms, and fog haze. For more details, see: Israel Meteorological Service and National Emergency Agency. 2023. Reference scenarios of extreme climate events in Israel. In Hebrew.

from updates to building standards for fire defense systems and thermal insulation, water systems, etc. Leveraging the Fire and Rescue Authority's detailed information on buildings' vulnerability to fires could help assess vulnerability to extreme climate events.

Other insights from the discussions included systems relevant to operational continuity, such as the health system, sensitivity of financial institutions, and economic sensitivity of local authorities. While critical for climate vulnerability evaluation, these were extensively discussed in other fields (health sensitivity and socio-economic sensitivity, respectively). Relevant indicators and selection considerations for these components will be discussed in their respective chapters in this report.

Proposed Indicators

The following sensitivity clusters were discussed in the field of operational continuity, along with suggested indicators for each cluster:

- **Water Supply**

The regular supply of high-quality fresh water is of utmost importance, ranking at the top of the systemic importance hierarchy[133]. The freshwater supply system is particularly sensitive to extreme climate events such as heatwaves and fires, while the desalination system is vulnerable to rising sea levels. Extreme fluctuations in precipitation levels, including periods of extreme drought and events such as floods and severe storms, are also expected to increase the system's sensitivity. For example, in 2018, Cape Town faced a near-collapse of its water supply system due to a series of drought years. In July 2021, Zhengzhou, China, experienced severe rain, and floods that led to the shutdown of its water supply system for over a week. Similarly, during the winter of 2022, numerous US states experienced water shortages following extreme cold that damaged supply infrastructures[134].

The proper functioning of the water supply system depends on other systems, mainly the electricity system, which is also sensitive to extreme climate events. Factors to consider when evaluating the sensitivity of a water supply system include the security of the energy supply for the local water system. This is reflected in the system's ability to produce electricity independently, its storage capacities to provide water in case of malfunctions in the national water conduction system, the quality and management of the water system, the maintenance level of supply lines, their physical resilience, and the system's level of connectivity[135].

When assessing the sensitivity of a water supply system, several questions need to be addressed, including whether the water storage capacity meets required standards, if standards incorporate considerations for climate change and lifestyle changes affecting water consumption, and

133. Grantham Research Institute on Climate Change and the Environment. 2023. What is water security and how is it impacted by climate change? August 7.

134. Wang D, et al. 2022. Increasingly frequent extreme weather events urge the development of point-of-use water treatment systems. npj Clean Water 5: 36.

135. Baghersad M, et al. 2021. Comprehensive Indicator Bank for Resilience of Water Supply Systems. Advances in Civil Engineering: 2360759.

if there is a defined value assigned to water sources and their quality within the standard. This is especially significant considering the increasing frequency of fires, particularly during severe heatwaves when water consumption is high and the probability of malfunctions in the water and electricity systems is elevated.

Entities that can provide relevant data for evaluation include the Water Authority, local authorities, Mekorot Water Corporation, urban water and wastewater companies, and agricultural water associations in rural areas. Data on the energetic independence of high-rise buildings may be available from the Planning Administration or the Ministry of Construction and Housing.

The indicators proposed for the water supply cluster are as follows:

a. The city's water storage capacity
b. Water quality in the city's water storage system
c. Level of dependency of the local water supply on the national supply system
d. Energy security of desalination facilities, wells, and pumping stations
e. Energy security of water systems in high-rise buildings

• Electricity Supply

Households, businesses, factories, and other entities rely on a consistent, high-quality supply of electricity, which can be vulnerable to damage during extreme climate events. Moreover, critical systems essential for the economy's operational continuity, such as fresh water supply, irrigation, communication, and wastewater treatment systems, all depend on a reliable electricity supply for their proper functioning. Critical sites and infrastructures like hospitals, airports, harbors, military and defense facilities, as well as transportation systems like trains and electric vehicles, also require continuous power supply. Therefore, the sensitivity of the electricity system is a crucial factor to consider when assessing an area's sensitivity to climate change, particularly in the context of extreme events. Many indicators relate to the security of the energy supply in specific areas, i.e., their dependency on the national grid and their ability to function properly in case of grid malfunction.

Entities that can provide relevant data for this evaluation include the Ministry of Energy, the Electricity Authority, Israel Electric Corporation, and Noga Ltd. Past data can offer insights into the current state and predictions for the future. Data on energy storage in specific areas may be available from the Planning Administration or regional planning authorities.

The indicators proposed for the electricity supply cluster are as follows:

a. Energy storage capacity in a specific area
b. Proximity to energy production sources
c. Proportion of production systems susceptible to reduced output due to rising temperatures
d. Response time to power outage events by area and event scale
e. Supply-demand ratio per region
f. Presence of energy production facilities in high-risk areas
g. Availability of technical teams in high-temperature conditions

- **Transportation and Mobility**

The ability to move freely and safely is essential in both typical and emergency situations, making the proper functioning of transportation systems crucial for operational continuity. Resilient land transportation systems (such as cars, trains, and buses), as well as aerial and naval transportation systems, are vital components of climate resilience.

Like other systems discussed, transportation systems are expected to be impacted by climate change, with the transportation sector being particularly sensitive to extreme events[136]. The increased frequency of floods and heatwaves is expected to lead to more frequent degradation of road asphalt. Additionally, the severity of rains may result in more frequent floods in lower and underground infrastructures. The rise in storm surges may intensify degradation of coastal infrastructures and restrict anchoring in ports. Extreme weather events are also expected to increase the probability of road accidents, cause deformations in railway tracks on hot days, limit the ability of airplanes to transport cargo, and disrupt takeoffs and landings. In addition, the operation of electric trains may be affected by power supply malfunctions, necessitating the development of an index to assess the proportion of trains and stations with backup power. Similarly, the increasing share of electric vehicles may be impacted by extreme conditions and disruptions to the electricity grid.

In the event of damage to private vehicle infrastructures, the critical importance of accessible, effective public transportation systems becomes even more significant, as does the pedestrian infrastructure in residential areas. Indices developed for evaluating the quality and resilience of these systems should be utilized[137,138]. Entities that can provide relevant data for such evaluations include the Ministry of Transportation and its infrastructure companies including Netivei Israel (National Transport Infrastructure Company), Trans Israel, Israel Railways, NTA (Metropolitan Mass Transport System), and Ayalon Highway. Additionally, national transport authorities such as the Israel Airport Authority, Civil Aviation Authority of Israel, and the Israel Port Authority can provide relevant data. Data regarding pedestrian infrastructure may be available from the Planning Administration or Survey of Israel.

The indicators proposed for the transportation and mobility cluster are as follows:

a. Access to public transportation
b. Proportion of electric vehicles
c. Resilience of roads and railroads to extreme events
d. Level of backup energy generation capacity for electric trains
e. Distance from critical emergency centers (health, fire services, etc.)
f. Number of access points to the area (in the case of increased risk for floods, fires)
g. Critical transportation infrastructure (airports, seaports, public transportation terminals) susceptible to flooding
h. Measure of walkability

136. Stav N and Naor N. 2023. Adaptation of the transportation sector to climate change. Ministry of Transportation, Israel Meteorological Service and Mimshak Program. In Hebrew.

137. Ministry of Transportation and Road Safety, National Authority for Public Transportation. 2023. An index bank for public transportation: Version No. 2.0. April. In Hebrew.

138. Shashua-Bar L, et al. 2016. Developing a walkability index adapted to local Israeli conditions. Ecology and Environment 7 (3): 289–290. In Hebrew.

- **Food Systems**

The food systems cluster encompasses local food production systems (agriculture), food transport and distribution systems, and food import systems. The latter rely on the proper functioning of both the import systems and the food production systems in the origin countries. Agricultural systems are highly sensitive to climate change, with changes in temperatures and precipitation patterns significantly affecting crop yields and supply continuity. Extreme climate events, though less frequent, can cause substantial damage, potentially leading to the complete loss of a season's yields[139].

All agricultural crops depend on specific climate conditions, but each crop has a different sensitivity threshold[140]. The impact of a climate event is not only determined by its nature but also by its timing. For example, the season in which a heatwave occurs is crucial; some crops are more susceptible to damage from a spring heatwave, while others are more affected by a summer heatwave. A heatwave during flowering phases and early fruit development can be particularly detrimental to yields.

In general, extreme changes in precipitation patterns, such as droughts and severe floods, have the most significant implications for agricultural systems. Israel's agricultural systems are relatively resilient to such impacts due to their reliance on stable water systems, including fresh water and supplemental sources such as treated wastewater. Israel employs systems to mitigate the impacts of extreme climate events as part of its mitigation and prevention efforts. These systems include active solutions like ventilators and sprinklers for plant crops and livestock, as well as passive solutions like nets for cooling. Water-efficient systems are also utilized. The availability of these systems is a resilience factor, while their absence constitutes a sensitivity factor.

The intersection of crop maps developed by the Ministry of Agriculture with exposure factors, sensitivity thresholds, and their timing will facilitate the assessment of the agricultural sector's vulnerability to climate change[141]. In addition to these considerations, food systems rely on the proper functioning of other systems, particularly a consistent water supply for irrigation and reliable electricity supply for cooling systems. Therefore, the availability of water for irrigation should be evaluated using indicators similar to those developed for the water supply cluster. Attention should also be paid to contingency plans in response to potential impacts on water supply, such as utilizing supplemental water sources like treated wastewater.

Furthermore, agriculture is an economically risky sector, and the realization of such risks can impact productivity and cause production slowdowns. Kanat (Insurance Fund for Natural Risks in Agriculture) provides farmers with insurance plans for damages resulting from extreme climate events; however, these programs do not provide full coverage[142]. Farmers without comprehensive insurance plans may face severe economic damage due to extreme events.

139. Amdor L. 2020. National food security in Israel. Yesodot. In Hebrew.
140. Toporov G, et al. 2019. Adaptation of the Israeli agricultural sector to climate change. Ecology and Environment 10 (4): 39–45. In Hebrew.
141. Ibid.
142. Finklestein I. 2020. Mitigating risks: why over-redemption insurance is preferable to indirect support in agriculture? Yesodot. In Hebrew.

Entities that can provide relevant data for the evaluation include the Ministry of Agriculture and Kanat, which holds comprehensive information on past events where agricultural crops were damaged during extreme climate events, as well as information on the extent of insurance coverage for farmers. The Water Authority can provide data on water availability for irrigation and the availability of alternative sources. The Yesodot Institute conducted a study on Israel's dependency on imported food, including a reference to the extent of climate vulnerability in origin countries[143]. However, the existing scientific infrastructure within the Ministry of Agriculture is insufficient for establishing reliable metrics for each of the following indicators, highlighting the need to improve data collection mechanisms within the Ministry.

The indicators proposed for the food systems cluster are as follows:

a. Share of agricultural crops protected by climate mitigation measures
b. Share of agricultural crops grown in climate adaptive interfaces
c. Crop diversity per geographic unit
d. Sensitivity of agricultural crops to reduced water supply
e. Sensitivity of agricultural crops to extreme events during critical periods
f. Degree of dependence on refrigeration during transportation, storage or processing
g. Degree of dependence on import from countries with high climate vulnerability
h. Share of agricultural land covered by comprehensive insurance

• Fire and Rescue Services

Efficient fire and rescue services are crucial for ensuring operational continuity, especially given the increasing frequency of fire events associated with anticipated climate trends[144]. Building standards related to fire safety requirements have been continually updated, creating a direct correlation (though not complete overlap) between the age of a structure and the extent of its fire protection. In addition to the degree of protection of structures, other factors relevant to assessing an area's vulnerability to fires include the density of the built area, the availability and quality of fire services, proximity to forested areas, and the availability of water for firefighting efforts. These factors are always relevant but become particularly important during extreme events.

The Fire and Rescue Authority has mapped approximately 500 localities based on their susceptibility to fire hazards, using unified criteria developed for this purpose[145]. Additionally, several countries have developed indices for assessing the quality and availability of fire services[146]. Another sensitivity factor is a high ratio of residents per housing unit, which complicates assistance and evacuation efforts

143. Amdor L. 2023. The climate crisis and our plate: How global climate change will affect food supply in Israel? Yesodot. In Hebrew.
144. The Ministry of Environmental Protection. 2019. Israel's Adaptation Plan to Climate Change. 1st Report. Submitted to the Government of Israel by the Climate Adaptation Administration in implementation of Government Resolution No. 4079 on Israel's adaptation to climate change. In Hebrew.
145. The Cabinet Secretary. Government Decision No. 1091 from 6.2.2022. A national program for managing forest fires. In Hebrew.
146. Crowe RP, Gardner B, and Fernandez AR. 2023. 2023 ESO Fire Index.

during extreme events[147]. Entities that can provide relevant data for evaluation include the Fire and Rescue Authority, the Planning Administration, and Survey of Israel, which hold information on forested areas (National Outline Plan 22 – National Plan for Forest and Forestation). The Central Bureau of Statistics presents data regarding the number of persons per room under its indices for quality of life, sustainability, and resilience.

The indicators proposed for the fire and rescue services cluster are as follows:

a. Age of structure
a. Structure density
b. Water availability for firefighting efforts
c. Quality and availability of firefighting services
d. Level of fire risk
e. Frequency of fire events
f. Number of residents per housing unit

• Wastewater Management

Wastewater management involves the continuous removal of wastewater from its point of origin and its treatment in wastewater treatment plants (WWTPs) to achieve a satisfactory quality level. The proper functioning of wastewater management systems is crucial for maintaining public health, environmental health, the quality of water sources, and a decent standard of living[148]. Like other systems discussed, the wastewater treatment system is entirely dependent on a reliable supply of electricity. Conversely, the food production system in Israel relies heavily on the proper functioning of WWTPs, which provide treated wastewater for irrigation. Extreme climate events, particularly flooding events, can directly affect the operation of WWTPs, especially those located in flood-prone areas. While larger WWTPs tend to be more resilient to weather impacts, the cost of failure to their proper functioning is significant, resulting in the discharge of untreated wastewater into open areas. WWTPs in Israel are flooded routinely, leading to the discharge of large amounts of untreated wastewater into beaches and the sea, risking bathers and damaging local ecosystems[149].

Entities that can provide relevant data for the evaluation include the Water Authority, water and wastewater corporations, and city associations for environmental protection.

The indicators proposed for the wastewater management cluster are as follows:

a. Energy security of wastewater pumping stations
b. Size of wastewater treatment facilities
c. Energy security of wastewater treatment facilities
d. Susceptibility of wastewater treatment facilities to flooding

• Communication Systems

Communication systems are vital for the functioning of civilians, businesses, infrastructure, and government institutions. Climate change poses a threat to these systems, leading to increased disruptions and malfunctions.

147. Flanagan BE, et al. 2011. A Social Vulnerability Index for Disaster Management. Journal of Homeland Security and Emergency Management 8 (1): 1–22.

148. The Government Water and Sewage Authority, the Ministry of Health, the Ministry of Environmental Protection and the Ministry of Construction and Housing. 2016. Wastewater pumping stations – public wastewater conveyance systems. In Hebrew.

149. Zalul. 2022. Winter season summary 2021–2022: Another polluted winter in rivers, beaches, and sea. In Hebrew.

Extreme weather events such as heavy rain, floods, and heatwaves can significantly impact communication networks, resulting in delays in providing emergency assistance and posing risks to lives, health, and resources, especially in isolated areas[150]. Malfunctions in communication systems can also delay the restoration of vital services like electricity, water, and health care during emergencies.

The risks to communication systems can be categorized into three main groups: risks to fixed communication systems (such as telephone and internet infrastructure using copper cables or optic fibers), risks to mobile communication systems (including cellular and satellite communication), and risks to digital communication centers (such as server farms)[151]. Vulnerability reports on the British communication system highlight that extreme events like strong winds and lightning storms pose significant risks to cellular infrastructures due to potential damage to antennas. Additionally, extreme rain events and high temperatures can also impact these infrastructures[152]. Floods present a significant risk to various communication infrastructures, especially when access to underground facilities is restricted during emergencies[153]. Maintenance teams may also face challenges in addressing system problems during extreme weather events. Importantly, communication systems in Israel are frequently updated and changed, leading to varying levels of sensitivity within systems. For example, copper cables are generally considered more resilient to moisture than optical cables[154].

The primary risk to the proper functioning of communication systems is their dependence on regular power supply. For example, in Northern England during Christmas of 2015, a power substation was damaged due to flooding. This led to a 30-hour power outage, resulting in a complete shutdown of cellular communication, internet, and radio services[155]. The floods inflicted damage on telephone line systems, restricting access to emergency calls to police, rescue, and emergency medical services. The floods also damaged telephone line systems, restricting access to emergency calls for police, rescue, and emergency medical services. In response to these events, many communication companies in Britain began developing defense measures against floods[156]. Additionally, a report published by the State of New York indicated that most malfunctions in communication systems during heatwaves were attributed to failures in electricity supply, stemming from demand and supply gaps[157].

150. UK Climate Risk. 2021. Telecoms and ICT Briefing; Findings from the third UK Climate Change Risk Assessment (CCRA3) Evidence Report 2021.
151. TechUK. 2016. The UK's Core Digital Infrastructure: Data Centres Climate Change Adaptation and Resilience. Voluntary submission to DEFRA on behalf of the ICT (information, communications and technology) sector under the Adaptation Reporting Power (second round of reporting) as defined by the 2008 Climate Change Act.
152. Adams P and Steeves J. 2014. Climate Risks Study for Telecommunications and Data Center Services: Report Prepared for The General Services Administration Riverside Global Science Solutions.
153. Ibid.
154. Ibid.
155. UK Climate Risk. 2021. Telecoms and ICT Briefing; Findings from the third UK Climate Change Risk Assessment (CCRA3) Evidence Report 2021.
156. TechUK. 2016. The UK's Core Digital Infrastructure: Data Centres Climate Change Adaptation and Resilience. Voluntary submission to DEFRA on behalf of the ICT (information, communications and technology) sector under the Adaptation Reporting Power (second round of reporting) as defined by the 2008 Climate Change Act.
157. Jacob K, et al. 2011. Chapter 10: Telecommunications. In Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation in New York State: Final Report. pp. 363–396.

The indicators proposed for the communication systems cluster are as follows:

a. Readiness of backup systems for emergency events
b. Level of maintenance of the physical communication infrastructure
c. Physical access to infrastructure during an emergency
d. Susceptibility of communication centers to flooding

• The Built Environment

The built environment in a specific area can significantly influence its sensitivity to climate change[158]. Characteristics such as the age of structures, their geometry, density, colors, materials, surface topography, energetic efficiency, and types of systems operated within them all play a role. Climate sensitivity is also affected by aspects of public spaces, including shading, the proportion of green and natural areas, biodiversity, the presence of crucial infrastructures, and the extent of surfaces covered by heat- and particle-inducing materials like asphalt.

The age of structures was highlighted in committee discussions as particularly significant, as building standards are regularly updated, contributing to the potential resilience of structures and residents against heatwaves, fires, water supply failures, and more. Technological advancements in insulation measures, fire extinguishing systems and internal water systems, enhance resilience. However, it was noted that despite legal requirements, the building sector does not always operate in accordance with standards for thermal insulation (SI 1045) or green building (SI 5281). High buildings are usually built to stricter standards, reducing their sensitivity to extreme climate events, but they can incorporate multiple materials and systems that, if inadequately planned, may increase sensitivity to climate change.

Open natural areas in urban environments mitigate negative climate change impacts, providing protection against severe weather[159]. Urban shading, created through careful planning, proper positioning of structures, and temporary shading means like canopies, is crucial for reducing sensitivity to global warming and heatwaves[160]. Large-scale tree planting is important for absorbing pollutants, reducing flood risks, and enhancing biodiversity[161]. However, studies indicate a correlation between urban areas inhabited by low socio-economic populations and low tree coverage, exposing these populations to extreme climate events due to limited access to cooling or heating devices[162]. Sometimes – as is the case with unrecognized Bedouin villages in the Negev –

158. World Green Building Council. 2022. Climate Change Resilience in the Built Environment: Principles for adapting to a changing climate.
159. Bar R and Sharon O. 2019. Cities in the era of climate change – vulnerability and adaptation arenas. Ecology and Environment 10 (4): 84–89. In Hebrew.
160. Tzarfati M and Shafran R. 2018. Sustainability and environment as a development tool in local government: Practical guide for local authorities. The Ministry of Interior and Mimshak Program. In Hebrew.
161. Berman Z, et al. 2022. Promoting street trees in Israeli cities: shading and cooling of the urban space using street trees as adaptation to climate change: summary and recommendations following a governmental roundtable on urban forestation. The National Economic Council. In Hebrew.
162. Ahn Y and Uejio CK. 2022. Modeling air conditioning ownership and availability. Urban Climate 46: 101322.

despite improvements like solar panel purchases, residents still face limitations in utilizing electricity for basic needs[163,164].

The ranking of structures according to the Neighborhood 360° measuring tool should provide information on the structure's energy consumption and insulation level[165]. Entities such as the Planning Administration and Survey of Israel can provide relevant data for the evaluation. Data on construction characteristics can be accessed through the Dwelling and Building Register of the Central Bureau of Statistics and local authorities. Information on structures built to the green building standard and energy efficiency ranking can be obtained from the Ministry of Environmental Protection.

The indicators proposed for the built environment cluster are as follows:

a. Age of structure
b. Implementation of SI 5281 Green Building Standard
c. Proportion of tall buildings
d. Building rating according to Neighborhood 360°
e. Underground infrastructure allocation
f. Above ground infrastructure in flood prone areas; particularly electricity infrastructure, hazardous materials, etc.
g. Proportion of urban shaded areas
h. Proportion of green spaces
i. Proportion of households without access to the electricity grid
j. Proportion of housing units with air conditioning and operational capacity

• Susceptibility to Flood Events

Floods present a significant and immediate danger to human lives, as well as causing substantial damage to property and infrastructure. For instance, in the winter of 2019-2020, seven people lost their lives in flood-related incidents, and between 2015-2020, Israeli Fire and Rescue services received between 400-600 calls for assistance during flood events[166]. Runoff during floods can contain disease-causing bacteria, particularly from wastewater discharge, which often occurs when urban drainage systems become overloaded due to unauthorized connections. Urban runoff also contains pollutants like fuels, oils, waste, and animal waste.

The occurrence of floods in urban areas is influenced by various factors, including the topographic location of the area, the density of buildings, and the effectiveness of drainage systems. The impact of flood events is also influenced by factors such as the availability of access roads to and from the flooded area and the accessibility of assistance teams. An area's sensitivity to floods can be assessed by examining the frequency of calls for assistance to urban help centers and the frequency of damage claims resulting from flooding incidents. Vulnerable populations are particularly sensitive to the

163. Kattan E, Halasah S and Abu Hamed T. 2018. Practical challenges of photovoltaic systems in the rural Bedouin villages in the Negev. Journal of Fundamentals of Renewable Energy and Applications 8: 3.

164. Shapira S, Shibli H and Teschner N. 2021. Energy insecurity and community resilience: the experiences of Bedouins in Southern Israel. Environmental Science and Policy 124: 135–143.

165. The Israeli Green Building Council and the Ministry of Construction and Housing. 2021. Neighborhood 360°, indices for planning and development of residential environments: new construction 1.2. In Hebrew.

166. The State Comptroller and Ombudsman of Israel. 2021. Preparedness of local authorities to floods and flooding events and their performance during the winter of 2020. In Hebrew.

impacts of flooding due to the quality of the structures they inhabit, population density per housing unit, preparedness for flooding events, and their ability to recover from damages[167]. These sensitivity factors are assessed in the socio-economic sensitivity field and are reflected in the final vulnerability value.

The Ministry of Agriculture has developed a national flood risk methodology based on key principles from the European directive on this subject. This methodology provides guidelines to drainage and stream authorities for developing flood risk management programs[168]. It includes tools to assess future floodplain locations along streams, estimate potential financial damage in floodplains, issue alerts regarding sensitive uses in floodplain areas, and more. Implementing this methodology has the potential to significantly assess the sensitivity of different geographical areas to flooding events.

Furthermore, according to the participatory flood vulnerability assessment approach, the history of flooding events in each area can be traced through interviews and a review of local and national media. Data for the evaluation can be obtained from the Ministry of Agriculture, the Planning Administration, and local authorities. Information on the frequency of emergency rescue calls is available through local authorities and the Fire and Rescue Authority. Matters related to flood management masterplans or the quality of drainage systems' maintenance operations are considered part of the adaptive capacity component and will not be mentioned under the sensitivity component of this work.

The indicators proposed for the susceptibility to flood events cluster are as follows:

a. Proportion of built areas lower than their surroundings
b. Proportion of built areas in surface depressions
c. Proportion of built areas located in a floodplain
d. Proportion of urbanized areas at risk of flooding due to rising sea levels
e. Susceptibility to accessibility constraints during flood events
f. Efficacy of drainage infrastructures
g. Proportion of impervious surface
h. Frequency of insurance claims for flood-related damage
i. Frequency of emergency rescue calls related to flooding
j. Distance from specialized rescue teams

167. Sayers P, et al. 2018. Flood vulnerability, risk, and social disadvantage: current and future patterns in the UK. Regional environmental change 18 (2): 339–352.

168. The Ministry of Agriculture and Rural Development. 2021. Guide for developing catchment area plans for flood risk management.

Photo by Brett Sayles

Chapter 3: Health Sensitivity

Background

The field of health sensitivity examines the degree to which populations, communities, or individuals are sensitive to the adverse health impacts of climate change. Assessing sensitivity in health is crucial because there is a direct correlation between physical and mental well-being and susceptibility to climate change impacts[169]. Climate change will affect public health through direct impacts of extreme weather events and indirectly through the spread of pests, disruptions in energy and water supply, and increased exposure to air pollution[170,171].

Sixteen public and environmental health experts participated in a discussion to delineate indicators for health sensitivity. These experts represented various sectors, including research and civil society institutions, as well as government ministries such as the Ministry of Health, the Ministry of Labor, and the Central Bureau of Statistics. Led by Dr. Ronit Ratzon from the Ministry of Health, the three-hour discussion extensively covered sensitivity factors in health. At its conclusion, 25 indicators were selected and organized into six clusters: age distribution, medical conditions, fertility and birth, access to healthcare services, pollution exposure, and occupation.

From the Literature

Climate change has been identified as the most significant health challenge of the 21st century[172], with the World Health Organization estimating that between 2030 and 2050, climate change will contribute to approximately 250000 cases of excess mortality annually[173]. A study published in Nature Medicine found that during the summer of 2022, the hottest season documented in Europe so far, over 60000 people died on the continent due to high temperatures[174]. However, climate change is not expected to impact the entire population equally, with certain groups expected to be more negatively affected than others[175].

169. Tong S and Ebi K. 2019. Preventing and mitigating health risks of climate change. Environmental Research 174: 9–13.
170. Berman T and Krigel K. 2020. Climate change and public health: Literature review, mapping health criteria and recommendations towards designing a Ministry of Health work-plan. The Ministry of Environmental Protection and The Israel society for Ecology and Environmental Sciences. In Hebrew.
171. Balbus J, et al. 2016. Ch. 1: Introduction: Climate Change and Human Health. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. U.S. Global Change Research Program, Washington, DC, pp 25–42.
172. Costello A, et al. 2009. Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. Lancet 373: 1693–1733.
173. WHO. 2014. Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. Geneva: World Health Organisation.
174. Ballester J, et al. 2023. Heat-related mortality in Europe during the summer of 2022. Nature Medicine 29: 1857–1866.
175. Environment and Health Fund and the Ministry of Health. 2020. Health and Environment in Israel 2020. In Hebrew.

The UNFCCC categorizes the health effects of climate change into three broad categories: effects directly linked to climate or weather, effects resulting from environmental changes caused by climate change, and effects resulting from socio-economic processes triggered by climate change[176]. Significant socio-economic factors such as low income, lack of financial security, or belonging to a minority group can increase health risks associated with climate change[177]. However, indicators representing these characteristics will be examined in the socio-economic sensitivity field and will be reflected in the final vulnerability value.

A feedback dynamic exists between the impacts of climate change and health vulnerability: Illness can exacerbate vulnerability to heatwaves, floods, and the spread of new diseases, which in turn increases morbidity and facilitates the introduction and dissemination of emerging diseases[178]. Furthermore, the proper functioning of the healthcare system, including clinics, hospitals, and emergency medicine, is heavily dependent on the proper functioning of other systems. This dependence begins with infrastructures such as continuous power supply and water provision, extends to the authorities' ability to deliver quality healthcare services during crises, and concludes with the proper functioning of financial systems. Indicators related to these characteristics will be examined in other sensitivity fields, such as the socio-economic field and the operational continuity field.

Several US states, including Michigan, Minnesota, and New York, have developed indices and maps for heat vulnerability. These tools integrate demographic, environmental, and socio-economic data to assess the population's susceptibility to heat-related impacts, a well-established risk factor scientifically linked to increased mortality[179]. Additionally, the Environmental Protection Agency has developed an index to assess the health vulnerability of communities to the risks of forest fires and smoke exposure. This index helps identify counties most sensitive and exposed to health implications from smoke exposure, facilitating the development of targeted mitigation efforts in these areas[180].

In Israel, the impacts of climate change on health are expected to be significant. The most immediate consequence is the occurrence of heatwaves or extreme heat, which can lead to heat stroke with severe effects on cardiac functioning or the nervous system. The elderly and individuals with chronic conditions are particularly vulnerable to this impact[181]. Rising temperatures also increase the risk of dehydration, especially among those engaged

176. UNFCCC. 2007. Chapter 8: Human Health. In Handbook on Vulnerability and Adaptation Assessment. Consultative Group of Experts on National Communications from Parties Not Included in Annex I to the Convention (CGE).
177. Tong S and Ebi K. 2019. Preventing and mitigating health risks of climate change. Environmental Research 174: 9–13.
178. Watts N, et al. 2015. Health and climate change: policy responses to protect public health. The Lancet 386 (10006), 1861–1914.
179. Conlon KC, et al. 2020. Mapping human vulnerability to extreme heat: A critical assessment of heat vulnerability indices created using principal components analysis. Environmental Health Perspectives 128 (9): 1–14.
180. Rappold AG, et al. 2017. Community Vulnerability to Health Impacts of Wildland Fire Smoke Exposure. Environmental Science & Technology 51 (12): 6674–6682.
181. Paz S, et al. 2019. The effects of climate change on public health in Israel: science and policy. Ecology and Environment 10 (4): 72–78. In Hebrew.

in prolonged outdoor work, the elderly, and individuals with high blood pressure[182]. Other impacts of extreme temperatures include kidney damage, an elevated risk of stroke, increased rates of premature birth, higher risks of birth defects and low birth weight infants, and exacerbation of chronic diseases such as cardiovascular and respiratory conditions[183]. An initial study found a sharp rise in mortality rates in Israel during heatwaves, with each heatwave leading to an average of 45 deaths[184]. Additionally, floods pose a direct health risk. In the winter of 2019-2020, seven fatalities were reported due to flood events[185]. Similarly, the increased frequency of fires and dust storms can also have direct health impacts.

Climate change is expected to impact water, air, and food quality[186]. For example, the incidence of Leptospirosis may increase as its outbreak becomes more feasible due to factors such as lower river levels and deteriorating water quality during dry periods. The risk of Campylobacter bacterial infection, which is transmitted through food and can lead to intestinal inflammation, also increases with rising temperatures[187]. Additionally, between 2001 and 2015, an increase was observed in the concentration of PM10 values during dust storms, with the highest values recorded in Be'er-Sheva. This change can be attributed to climate change[188]. The impacts of climate change are more pronounced in vulnerable populations, including infants, the elderly, and minorities. This vulnerability is further exacerbated in densely populated urban areas due to the urban heat island phenomenon and the strain on infrastructures.

Additional health impacts resulting from climate change may arise due to changes in the geographical distribution of diseases transmitted by pests. Examples include West Nile fever, transmitted by the common house mosquito (Culex Pipiens), and Leishmaniasis, also known as Jericho Rose disease, spread by the Leishmania parasite and transmitted by the bite of an infected sand fly. In recent years, an increase in the spread of these diseases has been detected in the region, likely as a result of heightened temperatures[189,190].

182. The Ministry of Environmental Protection. 2019. Israel's Adaptation Plan to Climate Change. 1st Report. Submitted to the Government of Israel by the Climate Adaptation Administration in implementation of Government Resolution No. 4079 on Israel's adaptation to climate change. In Hebrew.
183. Environment and Health Fund and the Ministry of Health. 2020. Health and Environment in Israel 2020. In Hebrew.
184. Yamin D and Shmueli E. 2022. Excess mortality in Israel due to heatwaves: Preliminary research for the Chief Scientist of the Ministry of Environmental Protection. In Hebrew.
185. The State Comptroller and Ombudsman of Israel. 2021. Preparedness of local authorities to floods and flooding events and their performance during the winter of 2020. In Hebrew.
186. Paz S, et al. 2019. The effects of climate change on public health in Israel: science and policy. Ecology and Environment 10 (4): 72–78. In Hebrew.
187. Rosenberg A, et al. 2018. Ambient temperature and age-related notified Campylobacter infection in Israel: A 12-year time series study. Environmental Research 164: 539–545.
188. Krasnov H, Katra I, and Friger M. 2016. Increase in dust storm related PM10 concentrations: A time series analysis of 2001–2015. Environmental Pollution 213: 36–42.
189. Environment and Health Fund and the Ministry of Health. 2020. Health and Environment in Israel 2020. In Hebrew.
190. Paz S. 2019. Effects of climate change on vector-borne diseases: An updated focus on West Nile virus in humans. Emerging Topics in Life Sciences 3(2): 143–152

Methodological Considerations

The World Health Organization (WHO) emphasizes the need to strengthen healthcare systems and implement policies that assess vulnerability to climate trends. This includes evaluating current vulnerabilities and anticipating future risks[191]. The WHO outlines an iterative process for vulnerability assessment, starting with defining evaluation objectives and the scale of examination. The subsequent steps involve evaluating current vulnerability, anticipating future vulnerabilities, establishing measures to address identified vulnerabilities, and creating mechanisms for ongoing improvement and evaluation. While vulnerability assessment is not exhaustive, it is essential for understanding health and climate risks, prompting the evaluation of existing databases, identifying knowledge gaps, and fostering collaborations to raise awareness of the impact of climate change on health vulnerability.

A recurring challenge highlighted in the discussions is the availability of comprehensive and up-to-date data for the indicators mentioned. Public health data are scattered across multiple entities, including the Ministry of Health, Health Maintenance Organizations (HMOs), and local authorities, and their accessibility and utilization are constrained by various limitations. Some data are only accessible at the local or urban levels, while others are available nationally. Statistical data, such as hospitalization and mortality rates, can provide information on certain indicators. However, processing this data may not always be accurate and could result in an unreliable representation of morbidity in specific areas.

Proposed Indicators

Following are the sensitivity clusters under the health sensitivity field, and the indicators proposed for each cluster:

• Age Distribution

Children and the elderly are particularly vulnerable to the impacts of climate change[192,193]. The discussion emphasized the importance of distinguishing between different age groups within these categories. The susceptibility of younger children differs from that of older children, and among adults, sensitivity varies with age[194]. For example, individuals aged 50-70 with blood vessel conditions are specifically susceptible to climate impacts[195]. Additionally, infants up to one year old are at an increased risk of sudden infant death syndrome (SIDS) when exposed to extreme temperatures[196]. The Central

191. World Health Organization. 2009. Protecting Health from Climate Change: Global research priorities.
192. Shannon MW, et al. 2007. Global climate change and children's health. Pediatrics 120: 1149–1152.
193. Balbus JM and Malina C. 2009. Identifying vulnerable subpopulations for climate change health effects in the United States. Journal of Occupational and Environmental Medicine 51: 33–37.
194. Lakhoo DP, et al. 2022. The Effect of High and Low Ambient Temperature on Infant Health: A Systematic Review. International Journal of Environmental Research and Public Health 19 (15): 9109.
195. Gamble JL, et al. 2016. Ch. 9: Populations of concern. In: The impacts of climate change on human health in the United States: A scientific assessment. U.S. Global Change Research Program, Washington, DC.
196. Chang AY, et al. 2022. Aging Hearts in a Hotter, More Turbulent World: The Impacts of Climate Change on the Cardiovascular Health of Older Adults. Current Cardiology Reports 24 (6): 749–760.

Bureau of Statistics collects the relevant data for evaluation within this cluster.

The indicators proposed for the age distribution cluster are as follows:

a. Adults over 70
b. Adults between 50-70
c. Youths under 18
d. Children under 5
e. Infants under one year

• Medical Conditions

Certain conditions and diseases increase individuals' susceptibility to the impacts of climate change[197]. Some sensitivity factors in the health field represent vulnerability to both chronic exposure to climate change and extreme events, such as respiratory diseases. Others specifically highlight vulnerability to extreme exposure alone, such as physical or mental disabilities that may hinder assistance efforts during disasters. While there was no consensus among discussion participants regarding which medical condition to consider as indicators for health sensitivity, there was broad agreement on the importance of cardiac and respiratory diseases, allergies, and psychiatric morbidity. Diabetes and high blood pressure increase the risk of kidney failure[198], and heatwaves have been linked to an increase in hospitalizations among individuals with these conditions[199]. The mortality rate in a community can also indicate its overall health sensitivity.

However, information on the occurrence of various medical conditions is not always available at the local level, and the data that is available are often dispersed across various entities, posing challenges in ensuring its availability to decision-makers. To ensure the validity and reliability of the vulnerability index, centralizing and categorizing data at the local level is crucial. The Ministry of Health maintains an up-to-date database of cancer, asthma, stroke, diabetes, and cardiovascular disease incidences, primarily at the national level rather than the urban or local level. While this data can be inferred from mortality or hospitalization records, this method has methodological disadvantages.

The Central Bureau of Statistics has data on certain cancer types, cardiovascular diseases, and diabetes categorized by geographical areas. Among the Ministry of Health's records, some are identified (based on identification numbers) and others are not. Identified records can provide data at the statistical area level, even if this processing is not routinely conducted. Identified records may include data on mortality and disabilities. The discussion suggested that the most accurate and reliable data on morbidity rates are available from various Health Maintenance Organizations (HMOs), but this data is not always publicly accessible.

Further work is needed to precisely identify the specific morbidity characteristics that serve as indicators for climate change in the health field. This work should include establishing accurate indices for each proposed indicator, determining which phenomena will be included in the indicator, according to which criteria, and their relative weights.

197. Balbus J, et al. 2016. Ch. 1: Introduction: Climate Change and Human Health. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. U.S. Global Change Research Program, Washington, DC.
198. Thomas MC, et al. 2015. Diabetic kidney disease. Nature Reviews Disease Primers 1 (1): 1–20.
199. Adélaïde L, Chanel O, and Pascal M. 2022. Health effects from heat waves in France: an economic evaluation. The European Journal of Health Economics 23: 1–13.

The indicators proposed for the medical conditions cluster are as follows:

a. Nonaccidental death rate
b. Respiratory disease prevalence
c. Heart disease prevalence
d. Psychiatric morbidity rate
e. Allergy prevalence
f. Obesity rate
g. Cancer prevalence
h. Diabetes prevalence
i. Hypertension prevalence

• Fertility and Birth

Pregnant women and their fetuses are particularly sensitive to the adverse effects of climate change[200]. The Central Bureau of Statistics categorizes fertility and birth data by cities in large localities.

The indicator proposed for the fertility and birth cluster is:

a. Proportion of pregnant women

• Access to Healthcare Services

The accessibility of healthcare services significantly affects communities' sensitivity to climate change[201]. Prior knowledge of health risks enables early adaptation and precautionary measures, while a healthy lifestyle reduces the likelihood of climate-related diseases. A robust community medicine system positively impacts residents' health, and the ability to receive healthcare services during crises helps mitigate potential damages[202]. Disabilities can create barriers to accessing necessary medical services, which are exacerbated by low socio-economic status. Conversely, low socio-economic status worsens the challenges faced by those with disabilities. Proper access to healthcare services is crucial, and its absence increases health sensitivity to climate change.

While there was broad consensus among discussion participants regarding the importance of this cluster in health sensitivity evaluation, measuring accessibility and collecting relevant data remain challenging. Possibly, this cluster should be included in the adaptive capacity component of the vulnerability index, as its assessment requires qualitative tools in addition to the quantitative tools used for most indicators under the sensitivity component.

Entities that can provide relevant data for evaluation include the Central Bureau of Statistics (for data on education level, from which health literacy can be inferred[203]), the Home Front Command, and Health Maintenance Organizations (HMOs) (for data on the utilization of relevant applications, from which digital health literacy can be inferred[204]). Data on mobility and communication difficulties, which can hinder access to healthcare services, are available through the Disability Administration

200. Gamble JL, et al. 2016. Ch. 9: Populations of concern. In: The impacts of climate change on human health in the United States: A scientific assessment. U.S. Global Change Research Program, Washington, DC.
201. Manangan AP, et al. 2014. Assessing Health Vulnerability to Climate Change: A Guide for Health Departments. Climate and Health Technical Report Series: Climate and Health Program, Centers for Disease Control and Prevention. CDC. National Center for Environmental Health. Division of Environmental Hazards and Health Effects.
202. World Health Organization and Health Canada. 2021. Climate Change and Health: Vulnerability and Adaptation Assessment.
203. Martin LT, et al. 2009. Developing predictive models of health literacy. Journal of General Internal Medicine. 24 (11): 1211–1216.
204. Richardson S, et al. 2022. A framework for digital health equity. npj Digital Medicine 5: 119.

in the Ministry of Welfare, while data on psychiatric hospitalizations is available through the Ministry of Health. The Ministry of Health also possesses data on the locations of medical services. By integrating these locations with the peripherality index of the Central Bureau of Statistics, the level of healthcare service accessibility can be determined. The School for Public Health at the Hebrew University has launched a national program for quality indices of community medicine, which can provide insights and data relevant to this cluster[205]. The Home Front Command may also have data on the location and accessibility of emergency medical services during emergencies.

The indicators proposed for the access to healthcare services cluster are as follows:

a. Health literacy rate
b. Access to digital health services
c. Physical access to community health services
d. Physical access to emergency health services
e. Prevalence of mobility difficulties (e.g., physical or mental disability)
f. Prevalence of communication difficulties (e.g., sensory or cognitive disability)
g. Quality measures in community medicine

• Pollution Exposure

Exposure to pollution, particularly air pollution, significantly increases the risk of various diseases[206]. Global warming exacerbates air pollution and its associated health impacts[207]. Therefore, communities already exposed to air pollution, whether acutely or chronically, are especially vulnerable to climate change, as their exposure is expected to rise further. Data on pollution exposure are available through the National Air Monitoring Array at the Ministry of Environmental Protection[208].

The indicator proposed for the pollution exposure cluster is:

a. Level of air pollution exposure

• Occupation

Employment characteristics significantly influence a person's vulnerability to the impacts of climate change. Extreme temperatures have been shown to increase the risk of work-related accidents[209]. Several key sectors will be affected by changing climate conditions, exposing employees in these sectors to escalating risks. These sectors include agriculture, as well as various service sectors such as waste disposal and gardening, where workers spend extended periods outdoors exposed to weather conditions. To develop a sensitivity value for this indicator, the proportion of employees in high-risk occupational sectors can be indicated in each

205. The Ministry of Health, The Israel National Institute for Health Policy Research and The Health Council. 2023. The national program for quality indicators in community healthcare in Israel: A report for 2013-2024. In Hebrew.
206. Ortiz AG, et al. 2021. Health risk assessments of air pollution. benefit analysis of reaching specific air quality standards and more. European Environment Agency.
207. US EPA. 2022. Change Adaptation Implementation Plan. US Environmental Protection Agency, Office of Air and Radiation.
208. E.g., the Ministry of Environmental Protection. 2021. Situation report for air quality in Israel for 2020. In Hebrew.
209. EPA. 2021. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. U.S. Environmental Protection Agency.

statistical area, utilizing data from the labor force survey of the Central Bureau of Statistics. Participants in discussions on health sensitivity agreed that the construction sector is among the industries facing considerable risks from climate change. High-rise construction poses increased risks for employees during heatwaves, storms, and dust storms[210], as well as the construction of infrastructure such as roads and interchanges. Data on this indicator can be available through the Safety Administration in the Ministry of Labor. In addition to delineating relevant indicators for this cluster, participants proposed developing a climate vulnerability value for each construction project, which could be integrated into the mandatory risk survey for such initiatives. Data on construction projects and their characteristics can be obtained from the Ministry of Construction and Housing and the Central Bureau of Statistics.

The Ministry of Labor is currently promoting an amendment to construction safety guidelines. This amendment proposes to establish a detailed online reporting requirement for construction site characteristics. Additionally, the Ministry's Safety Administration is advocating for reporting regulations regarding work-related diseases and accidents, which would include a requirement to report incidents of heat strokes experienced by workers. This reporting system will facilitate the coding of different variables, enabling their subsequent processing for use in developing the proposed climate index. The Safety Administration also proposes the development of an online set of voluntary tools, facilitated by government authorities responsible for innovation. These tools will allow construction companies to assess solutions provided to workers on site, such as online monitoring of workers' body temperatures or the use of heat-sensitive clothing. This information layer will contribute to refining the index, extending from the individual site level to the local authority level.

Furthermore, regarding risks in the agriculture sector, the Safety Administration in the Ministry of Labor is collaborating with the Ministry of Agriculture to develop a GIS-based pest control reporting log as part of an amendment to regulations on pesticides. According to the proposed regulations, the use of this log will be mandatory, allowing the collection of data on the extent of employment in agricultural fields and hours of work. This data can serve as a basis for developing an indicator for climate sensitivity in open agricultural areas.

The indicators proposed for the occupation cluster are as follows:

a. Proportion of individuals in construction or agriculture
b. Number of construction sites involving elevated work or infrastructure development

210. Roelofs C and Wegman D. 2014. Workers: the climate canaries. American Journal of Public Health 104 (10): 1799–1801.

Photo by Avi Theret on Unsplash

Chapter 4: Environmental Sensitivity

Background

The Environmental Sensitivity field focuses on evaluating and characterizing the anticipated impact of climate change on the environment in Israel. Climate change is considered a central factor threatening biodiversity, and its impacts are expected to intensify in the future[211]. This major change adds to existing pressures on ecological systems, including diminishing natural open areas, over-exploitation of natural resources, and water, soil, and air pollution, as well as an increase in the number of invasive species. Some habitats are already vulnerable and demonstrate reduced adaptive capabilities due to these pressures, making the threat to biodiversity from climate change increasingly pronounced.

A report published by the Society for the Protection of Nature in Israel in March 2023, which explores the relationship between climate systems and ecological systems, noted that the rate of ecosystem changes in Israel is notably more pronounced compared to other countries worldwide. This is due to Israel's geographic location in the rapidly warming Middle East, as well as its position as a meeting point between continents and climate regions, which increases species sensitivity[212].

Seventeen experts, including representatives from the Ministry of Environmental Protection, the Central Bureau of Statistics, and academic and civil society institutions, participated in the discussion on Environmental Sensitivity. Led by Dr. Amiel Vasl from the Ministry of Environmental Protection, this three-hour discussion led to the selection of 20 indicators, organized into five clusters: biodiversity, habitat – biotic characteristics, habitat – abiotic characteristics, pollution exposure, and benefit to humans.

From the Literature

An intricate relationship exists between ecosystems and the climate[213]. Climate change poses significant threats to natural ecosystems, particularly those already vulnerable or degraded due to human activities. These ecosystems will face increased pressures as a result. Additionally, changes in ecosystem characteristics, such as disruptions in global water, carbon, and nitrogen cycles, will influence climate change. A joint report by the IPBES and the IPCC emphasizes the interconnected nature of direct and indirect factors affecting both climate change

211. Ben-Moshe N and Renan I (eds.). 2022. The State of Nature Report 2022: Trends and Threats volume. Hamaarag – Israel National Ecosystem Assessment Program, Steinhardt Museum of Natural History. In Hebrew.

212. Lotner-Lev T, Liberty S and Mizrachi S. 2023. The bidirectional relationship between climate systems and ecological systems. Society for The Protection of Nature in Israel. In Hebrew.

213. Ibid.

and biodiversity. It underscores that each trend significantly impacts human well-being, especially when their synergistic effects are considered[214].

In the United States, the National Wildlife Federation has published a guide on climate change vulnerability assessment. The guide aims to assist decision-makers in formulating adaptation plans[215]. It acknowledges the inherent complexity in assessing the vulnerability of species and habitats, recognizing the uncertainties surrounding the diverse pressures affecting them. The vulnerability assessment outlined in the guide combines qualitative (expert opinions) and quantitative methods. The selection of the appropriate method for each evaluation component is based on data accessibility, budget, and time constraints.

Environmental assessments play a dual role in adaptation plans. Firstly, they provide insights into which species and habitats are most vulnerable to climate change. Secondly, these assessments can identify the specific pressures responsible for rendering certain systems and species more vulnerable than others. Identifying vulnerable species and habitats, and outlining the impact chains leading to this vulnerability, significantly contributes to decision-making processes regarding resource allocation and the management of conservation efforts.

In Florida, the Climate Adaptation Explorer initiative, led by researchers from the Conservation Biology Institute Organization in collaboration with other conservation and environmental organizations, has developed a detailed tool for assessing the impact of climate change on Florida's unique species and habitats[216]. Like the current report, this tool involves the use of quantitative indicators combined with expert opinions to assess species vulnerability, known as the standardized index for vulnerability and value assessment.

For this tool, thirty indicators were selected, including 12 exposure and sensitivity indicators (e.g., sea-level rise and the presence of key at-risk species), six indicators related to limited adaptability (e.g., genetic diversity), seven indicators measuring conservation value (e.g., endemism level), and five indicators related to data availability (e.g., scientific literature publications). The tool is designed as an Excel spreadsheet where experts assign a rank between 1 to 6 for each indicator (or 0 when there is insufficient data). The weights for each indicator were established by the tool designers. To conduct the vulnerability assessment, a team of experts with relevant scientific and academic backgrounds was selected, with a minimum of at least two experts assigned to evaluate each species.

NatureServe, a non-governmental organization, has developed two separate tools for assessing environmental vulnerability to climate change. These tools aim to provide science-based support for nature conservation initiatives, land planning, and decision-making processes. The organization published the Climate Change Vulnerability Index: Species and the Climate

214. IPBES-IPCC Co-Sponsored Workshop. 2021. Biodiversity and Climate Change: Scientific outcome.

215. Glick P, Stein BA, and Edelson NA (eds.). 2011. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. National Wildlife Federation, Washington, D.C.

216. Reece JS and Noss RF. 2014. Prioritizing species by conservation value and vulnerability: a new index applied to species threatened by sea-level rise and other risks in Florida. Natural Areas Journal 34 (1): 31–45.

Change Vulnerability Index: Ecosystems[217,218]. This distinction was made based on the understanding that different levels of resolution require specific methodological responses for each assessment framework[219]. Both indices serve as tools to translate scientific data into operational guidelines. The species index, targeted at experts from academia, government, and civil society institutions, is designed as a spreadsheet that has undergone several version updates over the years. The tool utilizes comprehensive data on species history and status, allowing for the prediction of the anticipated impact level for each species by cross-referencing current trends with future exposure factor. The species index includes 23 sensitivity indicators, with information on 13 of them deemed sufficient to evaluate vulnerability levels. These indicators are weighted numerically, and the cumulative score is translated into a categorical vulnerability score using a five-point scale, ranging from "not vulnerable at all" to "highly vulnerable". This assessment of vulnerability helps decision-makers, field researchers, and other stakeholders develop informed, science-based adaptation strategies.

Every few years, Israel publishes the State of Nature Report, which aims to establish a scientific knowledge base on the state of the natural environment in the country. The report encourages sustainable, informed policy for managing open landscapes and biodiversity[220]. It is published by the National Program for Ecosystem Assessment (Hama'arag), a collaboration of experts from the Ministry of Environmental Protection, the Nature and Parks Authority, and the Jewish National Fund – KKL-JNF. The initiative is supported by the Steinhardt Museum of Natural History and involves collaboration with independent scientists.

Since 2012, the findings of the State of Nature Report have been based on analyses of monitoring data from the National Terrestrial Biodiversity Monitoring Program. This program aims to identify trends and changes that indicate impacts on ecological diversity and its systems[221]. The country is divided into nine ecological units, and specific processes are monitored in each unit by tracking biological indicators from different taxonomic groups. These analyses provide a clear picture of the effect of human activity on various ecological communities and allow for comparisons with previous reports. The report considers climate change a significant threat to Israel's biodiversity, with notable sensitivity observed in freshwater aquatic ecosystems and some desert areas. However, there is insufficient knowledge in this field, and the continuation of monitoring activities is crucial for conducting an informed assessment of climate change impacts on Israeli ecosystems[222].

217. NatureServe. 2016. Guidelines for Using the NatureServe Climate Change Vulnerability Index.
218. Comer PJ, et al. 2019. Habitat Climate Change Vulnerability Index Applied to Major Vegetation Types of the Western Interior United States. Land 8 (7): 108.
219. Young BE, et al. 2012. Rapid assessment of plant and animal vulnerability to climate change. In: Brodie J, Post E, and Doak D (eds.). Wildlife Conservation in a Changing Climate. Chicago: University of Chicago Press. pp. 129–152.
220. Ben-Moshe N and Renan I (eds.). 2022. The State of Nature Report 2022: Trends and threats volume. Hamaarag – Israel National Ecosystem Assessment Program, Steinhardt Museum of Natural History. In Hebrew.
221. Sorek M and Shapira I (eds.). 2018. The State of Nature Report 2018. Hamaarag – Israel National Ecosystem Assessment Program, Steinhardt Museum of Natural History. In Hebrew.
222. Ben-Moshe N and Renan I (eds.). 2022. The State of Nature Report 2022: Trends and threats volume. Hamaarag – Israel National Ecosystem Assessment Program, Steinhardt Museum of Natural History. In Hebrew.

Methodological Considerations

The environmental sensitivity field differs fundamentally from the other sensitivity fields discussed in the expert committee (socio-economic sensitivity, health sensitivity, and sensitivity in the operational continuity field) because it focuses on ecosystems rather than humans. This unique focus presents several methodological challenges that require special attention.

One key challenge is distinguishing between chronic exposure to changing climate conditions and exposure to extreme events. While this distinction applies to all sensitivity fields, experts emphasized that, for the environmental sensitivity field, the effects of chronic exposure are equally significant as extreme events[223]. For example, the gradual warming trend can lead to habitat loss, population migration, competitive exclusion of local species, changes in activity patterns of various species, and more. Therefore, it is crucial that selected indicators reflect these gradual influences rather than just focusing on extreme events like severe heatwaves, floods, fires, and dust storms, which are more relevant to human health and social systems.

A distinction exists between assessing the sensitivity of species and the sensitivity of habitats. Global research has focused on identifying climate-sensitive plant and animal species and conducting in-depth monitoring of these species[224,225]. However, assessing the vulnerability of a specific species is complex due to the multitude of species in each geographical area, the movement of species between areas, and the diverse responses of different species to climate change[226]. In addition, there is limited reliable and comprehensive data and significant knowledge gaps regarding how species are impacted by climate change[227,228]. Additionally, those responsible for managing open landscapes often face limited resources.

Another approach advocates for assessing habitat sensitivity to climate change rather than the sensitivity of specific species[229]. This involves examining the structure and diversity of populations in a geographical area, as well as changes in its physical environment. Assessing changes in a specific habitat involves noting alterations in population composition, such as shifts in processes and patterns (e.g., habitat fragmentation or the emergence of invasive species), and trends in the habitat's abiotic environment (e.g., impacts to the hydrological cycle or changes in soil structure, composition, and features). Assessing a habitat's vulnerability also allows for more reliable standardization, enabling comparisons between different habitats at a national level. A significant challenge to this approach is the substantial

223. Nunez S, et al. 2019. Assessing the impacts of climate change on biodiversity: is below 2°C enough? Climatic Change 154: 351–365.
224. NatureServe. Climate Change Vulnerability Index: Species.
225. WWF. Climate Change Vulnerability Assessment for Species.
226. Young BE, et al. 2016. Guidelines for Using the NatureServe Climate Change Vulnerability Index. NatureServe.
227. Williams JW, et al. 2022. Climate sensitivity and ecoclimate sensitivity: Theory, usage, and past Implications for future biospheric responses. Current Climate Change Reports 8: 1–16.
228. Ben-Moshe N and Renan I (eds.). 2022. The State of Nature Report 2022: Trends and threats volume. Hamaarag – Israel National Ecosystem Assessment Program, Steinhardt Museum of Natural History. In Hebrew.
229. NatureServe. Climate Change Vulnerability Index: Ecosystems.

differences between habitats in terms of available knowledge, expected impacts, and abiotic predictions. For example, marine habitats are highly sensitive to pollution, freshwater aquatic habitats are sensitive to eutrophication, and dry habitats are sensitive to desertification. Despite these differences, the index should allow for comparisons between different habitats. Although not without challenges, the discussants concluded that the habitat assessment approach is favorable, as reflected in the number of indicators proposed by the participants.

A methodological challenge is collecting comprehensive and up-to-date data on the indicators mentioned below and processing them reliably to serve as indicators for the index. The most comprehensive sources currently available include the State of Nature Report by the Hama'arag, the biodiversity index developed by the Hama'arag, and the Central Bureau of Statistics. Data on the abiotic characteristics of habitats are available from the Geological Institution and the Water Authority. Data on an area's level of protection and its exposure to anticipated pollution are available from the Ministry of Environmental Protection, the Planning Administration, and Survey of Israel.

Proposed Indicators

Following are the sensitivity clusters discussed for the environmental sensitivity field, and the indicators proposed for each cluster:

• Biodiversity

The negative impacts of climate change on biodiversity are significant, affecting natural ecosystems both globally and locally[230]. The conversion of natural areas into developed areas has been the primary cause of a 75% loss of plant and animal species worldwide over the last 500 years. Climate change acts as an additional stressor, intensifying the existing threats to ecosystems and endangering many species at risk of extinction. In this context, the diversity of species in a geographical area or habitat is crucial for an ecosystem's resilience. Greater species diversity leads to a higher rate and complexity of interactions among the different components of the ecosystem. This complexity is important because any impact on one element of the ecosystem can alter its internal dynamics and, consequently, the functioning of the entire system[231]. Therefore, greater complexity implies a reduction in the relative weight of each individual element, which enhances the ecosystem's ability to withstand and recover from disturbances.

The indicators for the biodiversity cluster aim to assess ecosystem sensitivity to climate change. Factors identified as indicating heightened sensitivity include species richness in the geographic cell and the rate of species loss. Key species in each area or habitat are crucial, as their loss increases the overall risk to the ecosystem. Therefore, the loss of key species is another indicator of sensitivity. Additionally, some species are already highly sensitive to warming trends, and their continued vulnerability poses a threat to their existence. Another indicator is

230. World Wildlife Federation. 2022. Living Planet Report 2022: Building a Nature-Positive Society.

231. Lipton D, et al. 2018. Ch. 7: Ecosystems, ecosystem services, and biodiversity. In: Impacts, risks, and adaptation in the United States: Fourth national climate assessment, volume II. U.S. Global Change Research Program, Washington, DC.

the likelihood of certain species reaching a point of no return, where they can no longer recover from impacts. Developing unified indices to identify these species and assess their proximity to the thermal threshold is essential. Lastly, the committee prioritized ecosystems of higher value when allocating resources for adaptation and conservation efforts.

The value of an ecosystem should thus also be considered as a sensitivity indicator for the biodiversity cluster. Data for this cluster will primarily be sourced from the biodiversity index developed by the Central Bureau of Statistics and the Hama'arag[232].

The indicators proposed for the biodiversity cluster are as follows:

a. Species richness
b. Species loss
c. Key species loss
d. Species proximity to the thermal threshold
e. Risk of ecosystem collapse
f. Ecosystem value

• Habitat – Biotic Characteristics

Environmental sensitivity can be assessed from two perspectives: one focusing on the sensitivity of species and another on the sensitivity of habitats. While the cluster of biodiversity addresses the sensitivity of species, the subsequent clusters focus on habitat sensitivity. The current cluster examines the biotic characteristics of habitats and includes three indicators. The first indicator is habitat sensitivity, which recognizes that different habitats exhibit distinct levels of sensitivity[233]. For example, wetlands are known to be highly sensitive[234]. Furthermore, various habitats are sensitive to different stressors: marine habitats are especially vulnerable to pollution[235], freshwater aquatic habitats are particularly sensitive to eutrophication[236], and dry habitats are highly susceptible to desertification[237]. The developed index will assess the specific sensitivity characteristics of each habitat in Israel.

Another indicator for this cluster is habitat diversity within a specific geographic area. This is based on the understanding that a diversity of habitats contributes to resilience against external pressures. Lastly, the cluster includes an indicator related to environmental flows. Environmental flows refer to the proportion of source water in a geographic area allocated to human needs versus the proportion allocated to the natural environment. This indicator, for which data is relatively available, has the potential to characterize a habitat's sensitivity level, particularly in arid and drought-prone regions. This indicator has been integrated into the environmental sensitivity index of the UN Environment Program[238].

232. E.g., the Central Bureau of Statistics. 2022. Well-being, sustainability, and national resilience indicators 2021. In Hebrew.
233. Gabay O, et al. 2014. The threats to biodiversity in Israel in an era of climate change: Advocating for the establishment of a national center for climate change research in Israel. Ecology and Environment 5 (2): 161–171. In Hebrew.
234. Avisar A, et al. 2022. Rivers under climate change. The Open Landscapes Institute. In Hebrew.
235. Farr ER, et al. 2021. An assessment of marine, estuarine, and riverine habitat vulnerability to climate change in the Northeast U.S. PLoS ONE 16 (12): 1–35.
236. Rodgers EM. 2021. Adding climate change to the mix: responses of aquatic ectotherms to the combined effects of eutrophication and warming. Biology Letters 17 (10): 1–6.
237. IPCC. 2019. Special Report: Special Report on Climate Change and Land. Chapter 3 – Desertification.
238. United Nations Environment Program. 2004. EVI: Description of Indicators.

The indicators proposed for the habitat – biotic characteristics cluster are as follows:

a. Habitat sensitivity
b. Habitat diversity
c. Balancing human and ecosystem needs in environmental flow management

• Habitat – Abiotic Characteristics

The abiotic characteristics of a habitat are a significant factor in its sensitivity to climate change[239]. Two indicators were selected for this cluster, both related to the level of impact already affecting the habitat's physical conditions. The first indicator assesses the extent of impact on soil characteristics, including features such as weathering, erosion, coastal cliff erosion, sedimentation, sand flow regime, and moisture content[240]. This indicator is relevant to terrestrial habitats and wetlands. The second indicator evaluates the extent of impact on water characteristics, including features such as flow regime, discharge rate, recharge, and groundwater levels[241]. This indicator is relevant to aquatic and wetland habitats.

The indicators proposed for the habitat – abiotic characteristics cluster are as follows:

a. Impact on soil characteristics
b. Impact on water characteristics

• Pollution Exposure

The sensitivity of a species or habitat to climate change is significantly influenced by other pressures and exposures it faces. The current cluster focuses on pressures stemming from human activity, specifically exposure to pollution. Species or habitats exposed to pollutants are less resilient and more sensitive to climate change. Since real-time data on pollution levels in a specific area is dynamic and unreliable, the risk level of an area to pollution could be characterized based on its proximity to pollution sources. This includes its location downstream from a wastewater treatment facility, its susceptibility to contamination from runoff water and wastewater, its proximity to human activities emitting noise and light pollution, and its proximity to hazardous industrial activities.

The discussions highlighted that geographic areas like nature reserves are more protected from pollution threats. This suggests that the more environmentally protected an area is, the less sensitive it will be to climate change.

The indicators proposed for the pollution exposure cluster are as follows:

a. Habitat located downstream from treated wastewater discharge
b. Risk of negative impacts from wastewater discharge
c. Proximity to human activity
d. Proximity to hazardous industrial activity
e. Level of environmental protection of the habitat

239. Glick P, Stein BA, and Edelson NA (eds). 2011. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. National Wildlife Federation, Washington, D.C.

240. IPCC. 2019. Special Report: Special Report on Climate Change and Land. Chapter 4 – Land Degradation.

241. Avisar A, et al. 2022. Rivers under climate change. The Open Landscapes Institute. In Hebrew.

- **Benefit to Humans**

Healthy environments and robust ecosystems play a crucial role in mitigating human impacts and are essential for the establishment of a healthy and functional society[242]. The UN Global Biodiversity Framework highlighted this linkage, emphasizing the overall contribution of biodiversity to protecting human welfare[243]. The agreement signed after the Global Biodiversity Framework conference in 2022 underscored that a balanced and sustainable relationship with biodiversity and the environment not only sustains life on the planet but also provides food, medicine, energy, clean water and air, and protection against natural disasters. Additionally, it enriches our cultural and leisure activities.

Another report by the IPCC emphasizes the interconnectedness between the absence of a healthy environment and human vulnerability, noting that socio-economically vulnerable communities face a higher risk of being affected by environmental vulnerabilities[244]. Environmental impacts can have adverse effects, socially and economically, not only on vulnerable communities but also on the quality of life and health of all people[245]. These impacts include the acceleration of desertification processes leading to a reduction in soil fertility, an increase in runoff discharge from agricultural areas leading to erosion and degradation, and impacts on water quality in the nearby environment, among others.

Part of the discussion focused on whether to include a sensitivity cluster that assesses the value of a habitat or area to humans. While all participants acknowledged the inherent value of ecosystems regardless of their contribution to human populations, there was agreement that this component should be included in the index, primarily for practical reasons. Identifying and characterizing the sensitivity of natural ecosystems that provide benefits to humans will facilitate the allocation of resources for their protection and restoration. The selected indicators to assess ecosystem value to humans are based on the four categories of ecosystem services outlined in the Millennium Ecosystem Assessment report[246].

The indicators proposed for the benefit to humans cluster are as follows:

a. Supporting services
b. Regulating and monitoring services
c. Provisioning services
d. Cultural services

242. Cardinale BJ, et al. 2012. Biodiversity loss and its impact on humanity. Nature 486 (7401): 59–67.

243. UN Environment Program, Convention on Biological Diversity. 2021. Post-2020 Global Biodiversity Framework.

244. Cardona OD, et al. 2012. Determinants of risk: Exposure and Vulnerability. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (Field CB, et al. (eds.)). A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 65–108.

245. EEA. 2020. Drivers of change of relevance for Europe's environment and sustainability.

246. Corvalan C, et al. 2005. Ecosystems and Human Well-Being: Health Synthesis. A Report of the Millennium Ecosystem Assessment.

Photo by Daniel Newman on Unsplash

Chapter 5: Integration Considerations

Background

As previously outlined in the introduction, a vulnerability index consists of three core components: exposure, sensitivity, and adaptive capacity. This chapter focuses on sensitivity, which encompasses four distinct fields, which vary in such characteristics as the exposure factors considered, the nature of anticipated impacts, the geographical scope, and the interactions among sensitivity characteristics. These differences create a fundamental asymmetry within the index, necessitating developers to address resulting challenges and limitations. Hence, a well-informed integration of vulnerability components, including the sensitivity fields, is crucial for developing a comprehensive and reliable index. The expert committee emphasized the importance of identifying and characterizing these components and developing informed responses to associated challenges.

Twenty-three experts participated in the discussion regarding the integration of sensitivity fields and overall vulnerability components. Participants included researchers from diverse fields such as earth sciences, geography, urban planning, local sustainability, environmental health, law, and public policy. Additionally, representatives from various governmental agencies (e.g., the Central Bureau of Statistics, Survey of Israel), civil society, research institutes, and local government participated. The three-hour discussion was facilitated by Omri Carmon from Ben-Gurion University.

From the Literature

A 2007 UNFCCC guide on vulnerability and adaptation assessment provides a toolbox for mapping, assessing, and measuring climate change impacts across sectors such as marine resources, water supply, agriculture, and public health[247]. The guide emphasizes that climate change impacts are interconnected across sectors and regions. Effects in one area can significantly affect others, sometimes more than the direct impacts of climate change. Therefore, decision-makers and stakeholders need to understand both direct and indirect effects in each area and sector. This understanding allows for accurate assessment of vulnerability levels, severity of change, and prioritization of adaptation actions. Two approaches can achieve this integration. First of these is cross-sectoral integration, which assesses the impact level of one sector on related sectors (For example, evaluating how climate change impacts on water supplies may indirectly affect public health), then aggregating all expected impacts to compare vulnerability across sectors.

247. UNFCCC. 2007. Handbook on Vulnerability and Adaptation Assessment. Consultative Group of Experts on National Communications from Parties Not Included in Annex I to the Convention (CGE).

Another tool for anticipating and assessing climate change effects is multi-sector integration, which helps understand impacts on society, sectors, areas, and communities. The effectiveness of this integration depends on its ability to include as many sectors, areas, and communities as possible. A unified measurement method can be simple, such as assigning a monetary value to impacts, a common approach in finance. However, this method may struggle to assign value to non-tradable goods and services like health or biodiversity. A more complex method uses macro-economic models to assess impacts across communities and sectors. While effective, this approach is complex and requires specific tools for each application. Integrated assessment models offer a third option. These models examine the climate system holistically and assess the effects of various climate and development scenarios (e.g., population growth, land use, greenhouse gas emissions, sea-level rise).

Methodological Considerations

Geographic Area Division

A guide from the UN Environmental Protection Agency on developing tools for assessing climate change impacts and vulnerability addresses the challenge of determining the geographic areas for vulnerability assessments[248]. Areas can be divided by political entities (regional authorities, local authorities) or non-political entities (habitats, catchment areas). Assessments can also be based on themes (environment, economy, society) or sectors (water, agriculture, transportation). These choices are significant because the selected method will create segmentation in the unselected division. For example, choosing a sector-based division would split the environmental theme across different chapters, while a habitat-based division would segment sectorial categorization. When designing a sensitivity assessment, the first step is to ask: sensitivity to what? Are we assessing sensitivity to extreme climate events, climate fluctuations, chronic exposure, or climate change in general? The answers to these questions will shape the methodology for sensitivity assessment.

In each chapter of this report, the relevant geographic segmentation is discussed. For socio-economic sensitivity to climate change, the statistical areas defined by the Central Bureau of Statistics have been highlighted. These same areas can also be used to assess sensitivity in the health field[249]. However, not all sensitivity characteristics can be precisely divided by geographic locations. For instance, the closure of major commercial centers due to flooding can significantly impact the financial resilience of a local authority. This impact cannot be solely characterized by examining data from the statistical area. Similarly, sensitivity in operational continuity involves infrastructures such as electricity, water, and transportation. Damage to these infrastructures extends beyond the specific area and affects other areas as well (e.g., an impact on a desalination facility affecting water consumers in remote areas). Additionally, statistical areas are generally not relevant for assessing environmental sensitivity, which focuses instead on habitats.

248. Bizikova L, et al. 2009. VIA Module Vulnerability and Climate Change Impact Assessments for Adaptation.

249. The Central Bureau of Statistics. 2022. Characterizing geographical units and their classification according to the socio-economic level of the population in 2019. In Hebrew.

Given these complexities, geographic segmentation for each assessment should be considered on a case-by-case basis, taking into account the nature of the assessment and specific needs. However, experts agreed that the choice of segmentation method should always prioritize the most significant users of the index, namely, local authorities. In areas outside the local authority's jurisdiction, the assessment would be the responsibility of the relevant national agency (e.g., the Nature and Parks Authority for open natural areas, the IDF for firing areas). Another challenge is that certain factors may introduce methodological complexity to the integration of sensitivity indicators. For example, certain exposure data may be relevant only for summer, while others only concern winter, each potentially related to different geographic areas. A complete overlap is not expected between a flood-prone area and an urban heat island-prone area. Some areas are sensitive mostly during the day (e.g., employment hubs), while others are more sensitive during the evening and nighttime (residential areas).

Adapting the Index to a Variety of Needs and Uses

During discussions, a key point emphasized was the importance of constructing an index that can serve diverse end-users, including government offices, local authorities, the business sector, civil society, and the defense system, among others. These users may have different needs and purposes, such as requiring sensitivity values for socio-economic risks of a heatwave or flood risks in the agriculture sector. To accommodate such varied usage, the index should be modular, allowing for flexible analysis of available data. Additionally, it is crucial that the index products are presented clearly. A protocol developed by the National Emergency Agency for local authorities was highlighted. This protocol, based on the Multi-Hazard Mitigation Planning methodology[250], outlines roles and responsibilities during emergencies in local authorities[251]. Participants suggested that the development of the vulnerability index should also align with this methodology.

When designing the vulnerability index, it is essential to clarify whether its purpose is to assess vulnerability in the present or to project future vulnerability based on climate predictions. Both approaches have their advantages. For characterizing future vulnerability, users should have access to the entire database to conduct tailored analyses, going beyond the predefined analyses offered by the index. They should be able to input various exposure scenarios, ranging from optimistic to pessimistic, and scenarios between significant emissions reduction to a business-as-usual scenario. Scenarios developed by the meteorological service and the national emergency agency can be utilized for this purpose[252].

While this work focuses on methodological principles and indicator selection for the index, the distribution of weight among the various index elements is crucial. Assigning weights to indicators should be conducted thoughtfully, recognizing that not all indicators carry equal significance. While the specifics of weight distribution are not covered in this work, a

250. E.g., FEMA. 2008. Local Multi-Hazard Mitigation Planning Guidance.

251. Federation of Local Authorities in Israel, National Emergency Agency, Home Front Command and the Ministry of Interior. 2019. Guidelines to the Emergency and Security Administrators at municipal emergency headquarters. In Hebrew.

252. Israel Meteorological Service and National Emergency Agency. 2023. Reference scenarios of extreme climate events in Israel. In Hebrew.

dynamic approach to weighting should be considered whenever feasible. This approach can accommodate the diverse needs and preferences of users by allowing greater importance to be assigned to some indicators over others.

Between Human Sensitivity and Environmental Sensitivity

The discussion around the anticipated effects of climate change and the most effective adaptation strategies is largely anthropocentric, centering on human beings. Within this framework, the potential impact on biodiversity and ecosystems is often viewed as just one aspect of the broader range of impacts affecting humans, given the interconnectedness of human well-being and health with ecosystem services. However, based on the insights of the experts involved in the discussions, this work asserts that ecosystems possess intrinsic value independent of human reliance on them.

It is crucial to note that the primary objective of this work is to develop a methodology for assessing sensitivity across four domains, with environmental sensitivity being one of these domains, to derive a single comprehensive vulnerability metric. This presents a methodological challenge regarding the ability of a single metric to adequately capture both human and environmental vulnerabilities. This challenge can be addressed through two approaches. According to the anthropocentric viewpoint, humans rely on the natural environment in its current state; thus, their well-being and the health of the environment are closely linked. Therefore, any environmental impact directly affects humans[253,254]. In this context, environmental sensitivity contributes to the overall human sensitivity, placing it on par with socio-economic and health sensitivities. All sensitivity domains, under this perspective, exist within the same framework[255].

On the contrary, and consistent with the expert opinions of most committee participants, the second approach asserts that the environment possesses intrinsic value. It would be shortsighted to reduce it to a mere system serving human needs, akin to the transportation system, for example. According to this perspective, environmental sensitivity may not necessarily need to be integrated into the uniform vulnerability index. Instead, it should be established as a distinct, stand-alone index. However, it is possible that users of this index may, for various reasons, prefer to treat the environmental sensitivity field as equivalent to the other fields of sensitivity to humans, considering it as an additional element within the total vulnerability assessment. The proposed index will accommodate this usage as well.

Suggestions for the Component of Adaptive Capacity

Vulnerability comprises three components: exposure, sensitivity, and adaptive capacity. This work focuses solely on sensitivity and does not address exposure or adaptive capacity. While exposure is distinct from the other components, differentiating between sensitivity and adaptive capacity is less clear-cut. One commonly accepted distinction sees sensitivity as characterized by quantitative indicators, whereas adaptive

253. Drimie S, et al. 2005. Human vulnerability to environmental change. Background Research Paper for the South Africa Environment Outlook.

254. IPBES-IPCC Co-Sponsored Workshop. 2021. Biodiversity and Climate Change: Scientific outcome.

255. Lewis PGT, et al. 2023. Characterizing vulnerabilities to climate change across the United States. Environment International 172: 107772.

capacity is typically expressed through qualitative indicators, such as the preparedness of the financial systems or the level of citizens' trust in governmental institutions[256,257]. Incorporating qualitative indices into the index is indeed crucial for understanding the sensitivity levels of diverse populations and formulating precise responses. For instance, studies show that climate vulnerability is influenced by cultural norms of immigrants, social capital, and prevailing perceptions of climate risks[258,259,260]. Vulnerability from socio-cultural factors can also lead to non-beneficial responses to climate adaptation, such as property theft and violence[261,262].

The roundtable discussions highlighted several socio-economic indicators that may not be suitable as sensitivity indicators but could be valuable as indicators of adaptive capacity. These include the challenge faced by lower deciles in raising sufficient funds locally to prepare for climate change impacts, and the similar challenges faced by local authorities in vulnerable communities[263,264]. Other indicators for adaptive capacity include proper administration and governance, efficiency in allocating public resources, and public trust in local authorities[265]. At the economy level, it was found that openness to international trade enhances economic stability, while lack of openness increases sensitivity to climate change impacts[266]. These indicators are relevant for adaptive capacity but are not discussed here, as this work focuses solely on sensitivity.

For the environmental sensitivity component, possible indicators for adaptive capacity include the extent to which public policy considers nature conservation and sustainability, the presence of monitoring and measurement regulations, the existence of climate change adaptation plans, the capacity of local authorities for enforcement and operation, and public awareness of habitat-specific risks.

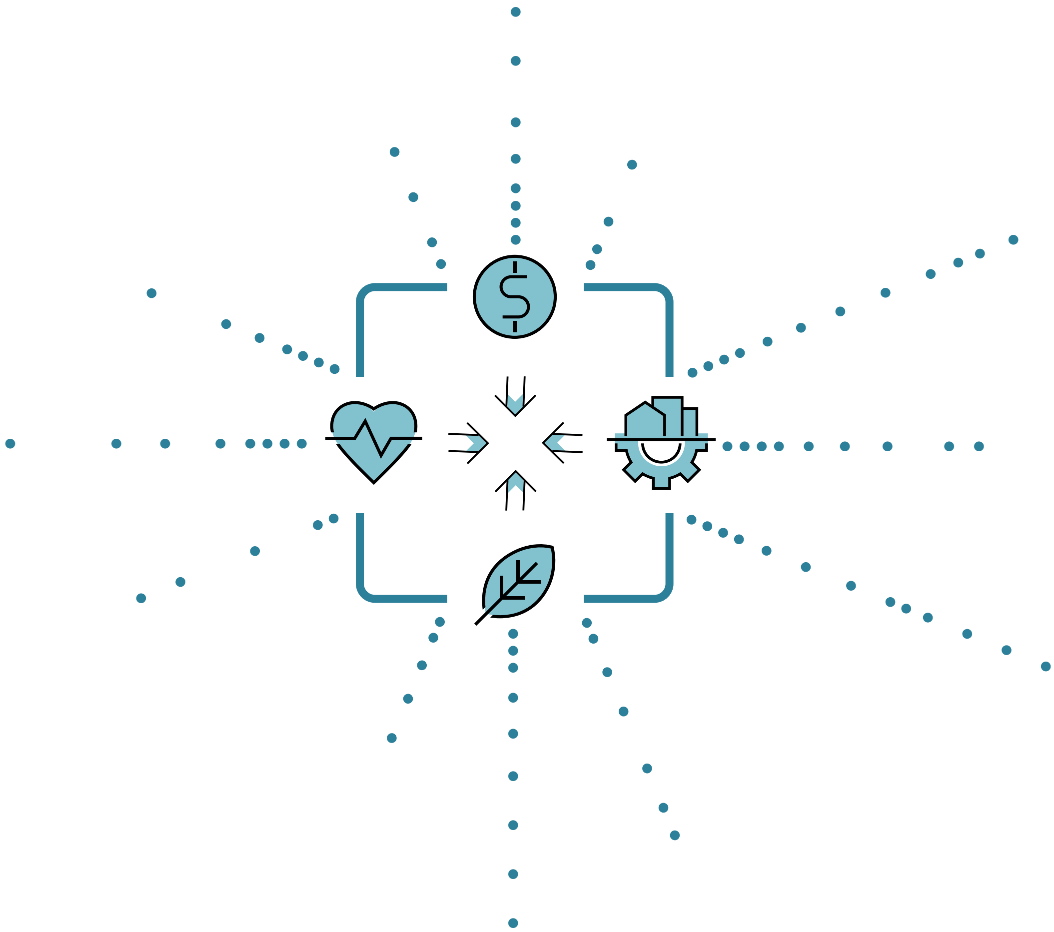
256. European Investment Bank. 2022. Joint methodology for tracking climate change adaptation finance.
257. Cologna V and Siegrist M. 2020. The role of trust for climate change mitigation and adaptation behaviour: A meta-analysis. Journal of Environmental Psychology 69: 101428.
258. Hansen A, et al. 2013, Extreme heat and climate change: Adaptation in culturally and linguistically diverse (CALD) communities, National Climate Change Adaptation Research Facility, Gold Coast, 101 pp.
259. Guardaro M, Hondula DM, and Redman CL. 2022. Social capital: improving community capacity to respond to urban heat, Local Environment 27 (9): 1133–1150.
260. Guardaro M, et al. 2022. Adaptive capacity to extreme urban heat: The dynamics of differing narratives. Climate Risk Management 35: 1–13.
261. Miles-Novelo A and Anderson CA. 2019. Climate Change and Psychology: Effects of Rapid Global Warming on Violence and Aggression. In Climate Change and Conflicts (E Gilmore and E Tennant, (eds.)). Current Climate Change Reports 5: 36–46.
262. Mukherjee A and Sanders NJ. 2021. The Causal Effect of Heat on Violence: Social Implications of Unmitigated Heat Among the Incarcerated. National Bureau of Economic Research. Working Paper 28987.
263. Ayalon O, et al. 2013. The Climate Change Information Center in Israel: Adaptation to climate change in local authorities. Haifa University, Tel Aviv University, Technion, Samual Neaman Institute and the Ministry of Environmental Protection. In Hebrew.
264. Rabinowitz D. 2011. Environment and Inequality. In: Sustainability: Vision, Values, Implementation (J Bernstein ed.). Heschel Center for Sustainability and the Ministry of Environmental Protection. In Hebrew.
265. Duit A. 2016. The four faces of the environmental state: environmental governance regimes in 28 countries, Environmental Politics 25 (1): 69–91.
266. United Nations. 2022. High Level Panel on The Development of a Multidimensional Vulnerability Index: Interim Report.

Usage of Data and Already Available Indices

Each chapter of this work identifies sources of relevant data for the discussed sensitivity fields. In some cases, the data is already processed into a specific index; in others, it is raw and requires processing into a relevant index; and in yet others, the data has not been fully collected, necessitating the creation of a collection mechanism. Ensuring that the data inputted into the index are of high quality, sourced from reliable entities, and constantly validated and improved is crucial for maintaining trust among the public and decision-makers in the index and its outcomes.

Utilizing existing and validated methodologies is preferred over developing new tools whenever possible. This applies to integrating vulnerability components into the general vulnerability index (exposure, adaptive capacity, and sensitivity) and integrating different fields within the sensitivity component (socio-economic, health, environmental, and operational continuity). Drawing from previous methodologies established by research teams worldwide, including those in Israel, can provide valuable insights and tools. Examples mentioned in discussions include the DALY index of the World Health Organization for assessing disease burden[267], and the FUAs methodology by the OECD for comparing socio-economic and spatial trends in cities[268]. Special attention should also be given to existing indices of the Central Bureau of Statistics, such as quality-of-life indices.

267.World Health Organization. 2020. WHO methods and data sources for global burden of disease estimates, 2000–2019.
268.Dijkstra L, et al. 2019. The EU-OECD Definition of a Functional Urban Area.



The Israel Society
of Ecology and Environmental Sciences

www.isees.org.il