15th International Scientific Conference
on Energy and Climate Change

Athens, 12-14 October 2022

The Regional Climate Adaptation Plan of Crete as a strategic planning cornerstone for the protection of the natural environment and the resilience of infrastructure in a climate hotspot area

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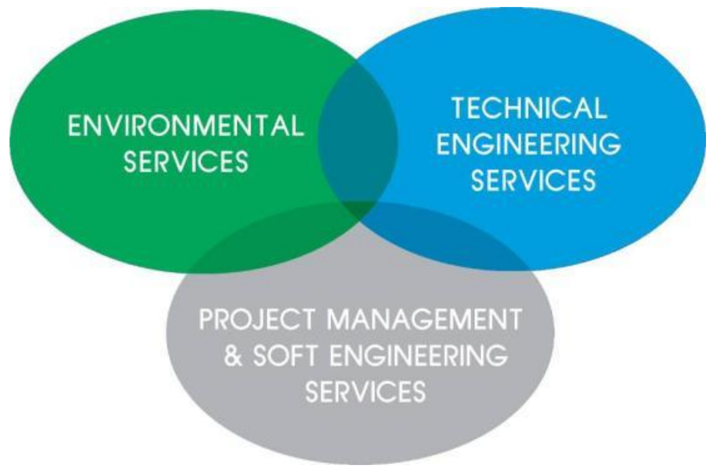

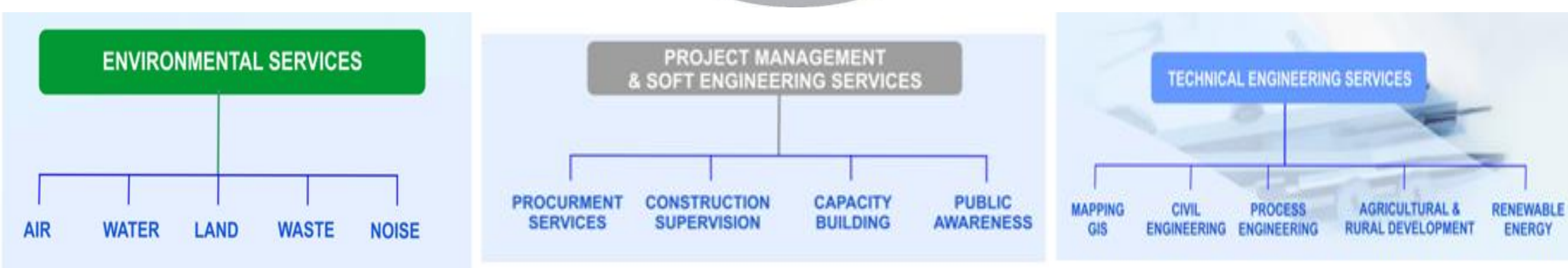

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- ✓ Ministries
- ✓ Waste Management Organizations
- ✓ Local Authorities
- ✓ Private sector

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Climate Change

Climate change has been taking place since the end of the 19th century and its **impacts are increasingly being noticeable i**n Europe and worldwide

According to the World Economic Forum's 2022 Global Risks Report, two of the five most serious global risks are related to climate change and include extreme weather events, and the failure to both mitigate and adapt to climate change (climate action failure)

Temperature rise is the most significant change and is directly related to **anthropogenic greenhouse gas emissions**

Direct impact of this continuous **increase in temperature** is the **melting of the polar ice caps**

And as a result, **sea level rise**

Other important changes in the global climate include **changes in the amount of precipitation** and the **more frequent occurrence of extreme weather events** such as droughts, heat waves, floods, hurricanes, storms, etc.

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Little bit of history

History of Climate Adaptation in Greece

- Interdisciplinary Committee on Climate Change Impact Assessment (EMEKA) of the Bank of Greece (2011)
- Greek National Climate Adaptation Strategy (NAS) (2016)
- Law 4414/2016 (Government Gazette 149/A/09-08-2016)
- Ministerial Decree 11258/2017 (Government Gazette 873/B/16-03-2017)
- Climate Law 4936/2022 (Government Gazette 105/A/27-05-2022)

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The Regional Climate Change Adaptation Plan of Crete

Elaborated as a legal obligation of the Region of Crete and supports the protection of Crete against:

- **Temperature rise**
- **Decrease of precipitation**
- **Increase in the frequency and intensity of extreme weather events** (floods, drought, windstorms, heatwaves, cold invasions/frosts, storm surges, etc.)
- **Sea level rise**

Flood events in Hersonissos Municipality (November 2020)

Forest Fire in Gouves (Hersonissos Municipality) (June 2021)

Landslide phenomena in the Prefecture of Chania, due to extreme weather events (February 2019)

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Development Steps of the Crete Climate Change Adaptation Plan

Assessment of expected climate change in the Region of Crete

↓

- Sensitivity Assessment
- Exposure Assessment
- Vulnerability Analysis

→

Determination of the sectors and geographical areas that are expected to be most affected by Climate Change in the Region of Crete

↓

Evaluation of available adaptation policies and options by sector

→

Prioritization and final selection of measures and actions per sector

↓

- Assessment of costs for the implementation of measures and actions
- Potential implementation bodies
- Plan's monitoring mechanism

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Climate Change in Crete (1)

- ✓ An **increase in average temperature** is expected at the Region, in all scenarios and time horizons
- In short term (2021-2040) mean temperature rise ranges between 1.35°C and 2.41°C
- Slightly larger increase in inland and mountainous areas & smaller in coastal areas
- Higher increase during the summer period compared to the whole year

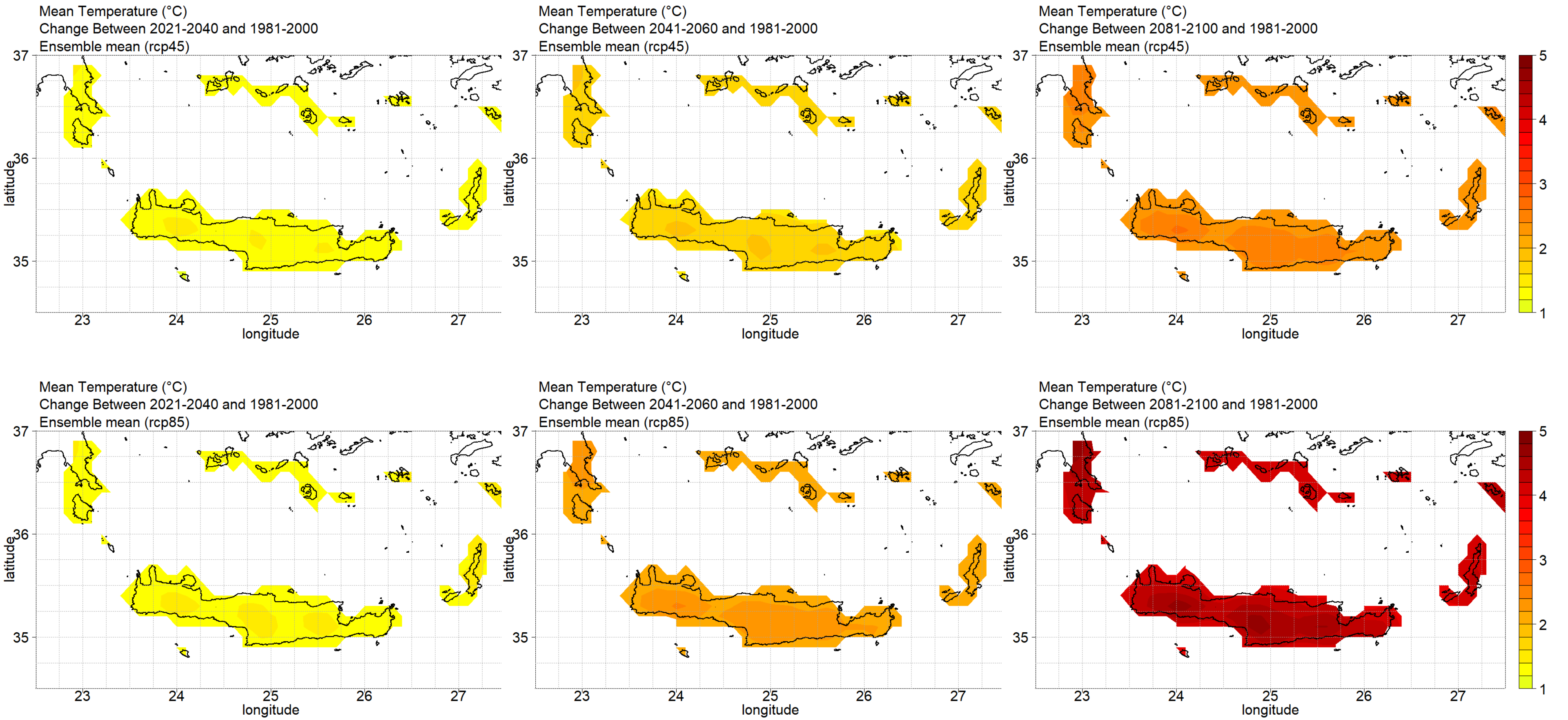
- ✓ **Electricity demand for cooling** (through the index of CDD) is expected to increase (opposed to energy demand for heating)

- ✓ **Growth season** is expected to be extended by 22 days/year (Positive impact, however, needs to be correlated with water availability)

- ✓ Number of days with a **very likely occurrence of fire (FWI index)**, increased by approximately 40 days (worst case scenario).

Climate Change in Crete

Mean Temperature Rise



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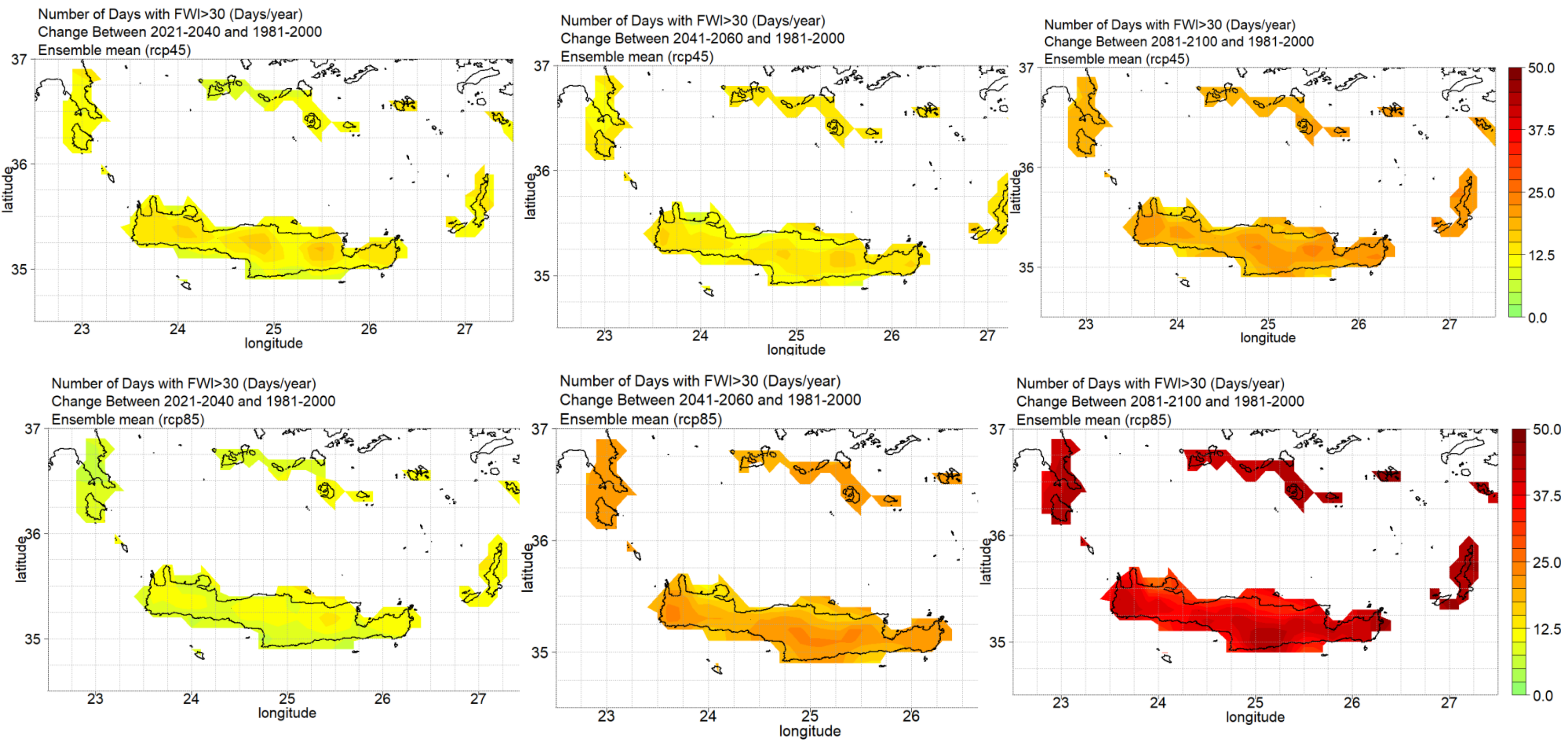
Climate Change in Crete

Increase in days with forest fire risk



Climate Change in Crete (2)

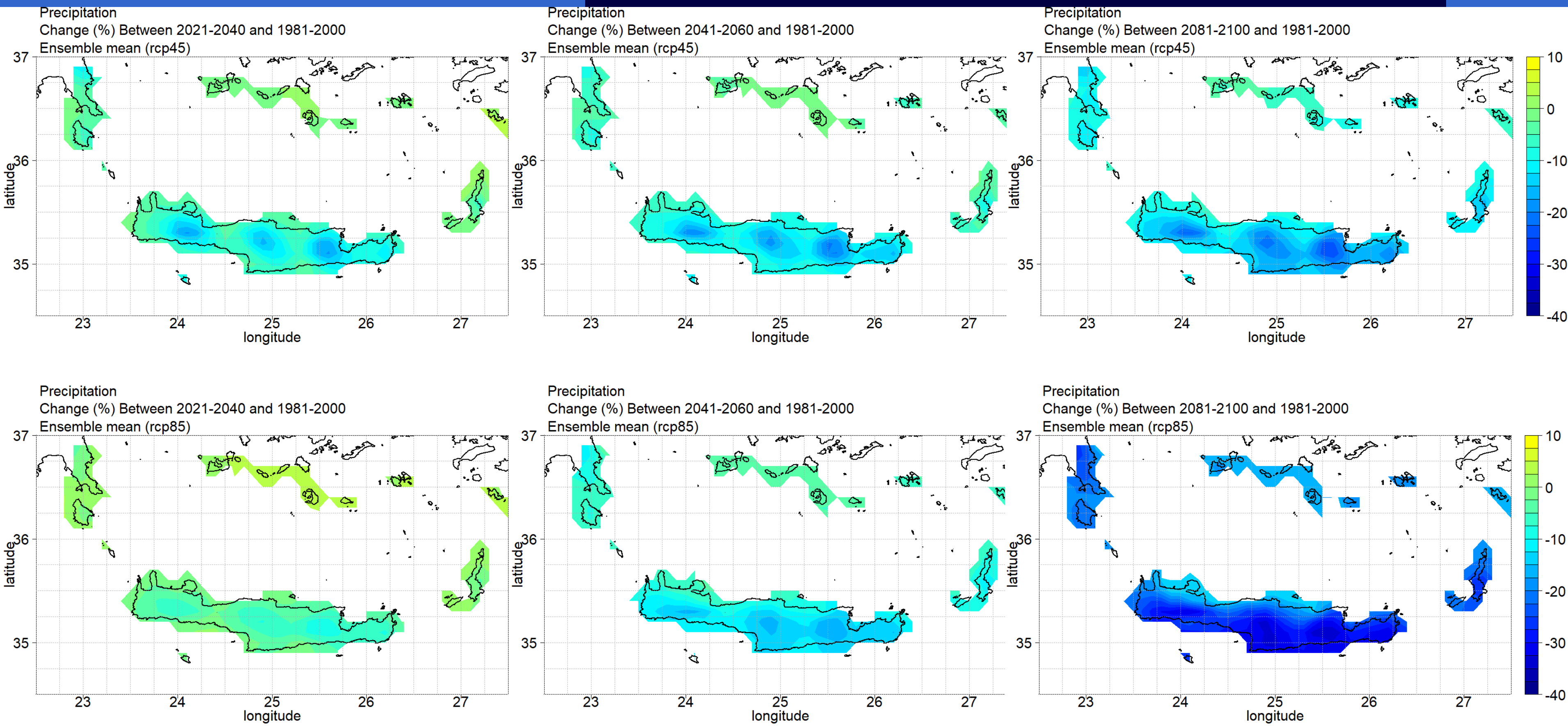
- ✓ **Gradual decrease in precipitation (both scenarios)**
- Highest decrease in mean precipitation value (Region as a whole) by 187mm (27%) in the period 2081-2100 (worst-case scenario)
- Increase in consecutive days without precipitation from about 5 to 25 days (**droughts**)
- Highest change of continuous dry days in Heraklion Prefecture (30 days/year, time horizon 2081-2100).

- ✓ In terms of **wind** (mean and maximum) no significant change is expected
- The number of days (during fire fighting season) with an average wind speed of more than 6B is unchanged - NE Crete is an exception (up to 20 additional days in the future)

- ✓ The **incoming short-wavelength radiation** reaching the surface will show a relatively small increase
- In the mountains significantly larger average annual increase (up to 8 Watt/m^2).

Climate Change in Crete

Change (%) of the mean annual precipitation



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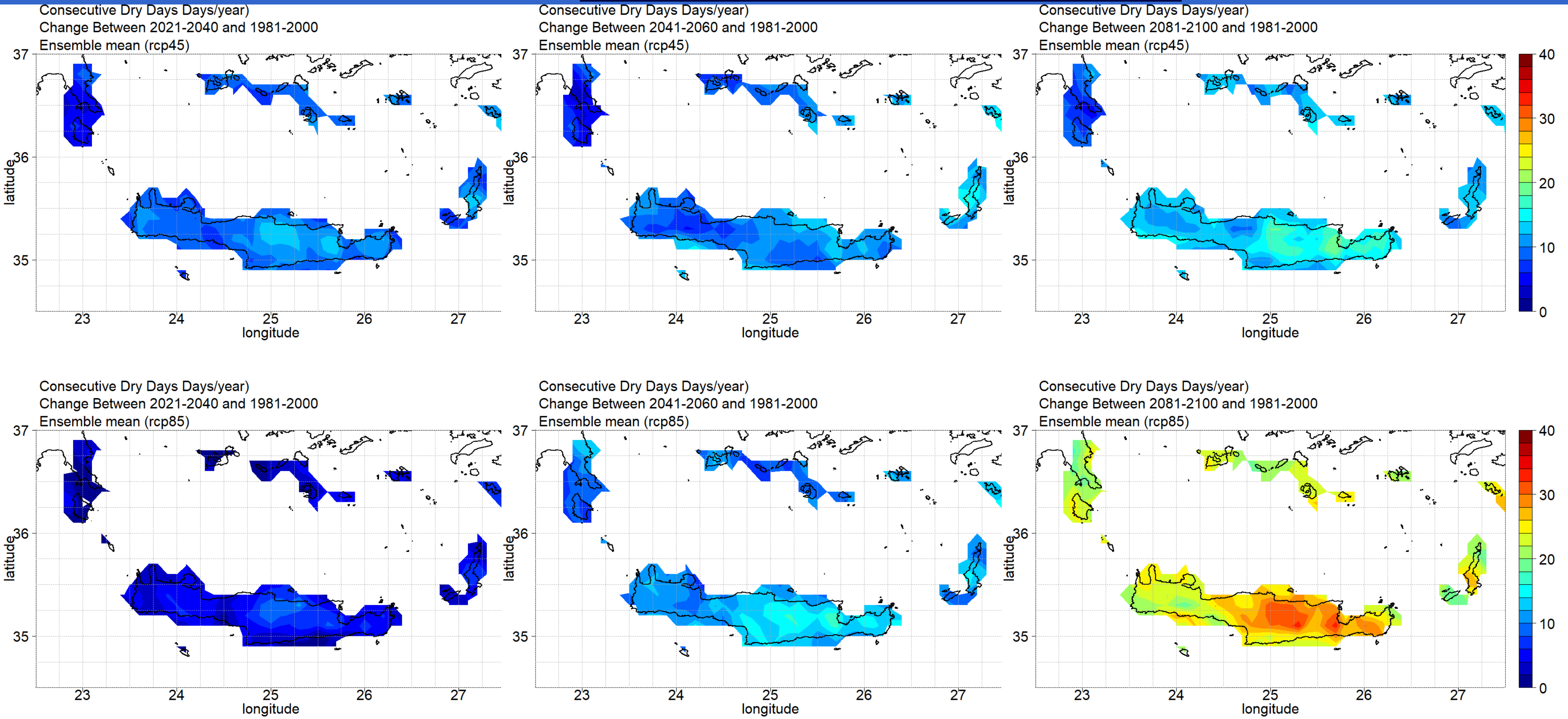
Climate Change in Crete

Change in number of dry days



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Climate Change in Crete (3)

- ✓ The number of days when the **maximum temperature will exceed 35°C** will increase from 3 days (two scenarios, near future) to 22 days (worst-case scenario, long term)

- Increase in number of days with a **maximum temperature above 37ºC** on average (total Region) from 1.5 days (two scenarios, near future) to 10 days (worst-case scenario, long term)
- Greater change in days with a **maximum temperature above 35°C** (RCP8.5 scenario, far future) in the Municipalities of **Phaistos and Gortyna** (increase > 30 days/year)
- Similar degree of increase for days with maximum temperature > 37ºC.

- ✓ Higher increase in the **number of days with Tmin > 20ºC (tropical nights)** in the coming decades, on average from 25 days (two scenarios, period 2021-2040) to 80 days (worst-case scenario, period 2081-2100)

➔ Increase in the **number of days per year with great discomfort for the population**, due to changes in temperature (combined with changes in humidity)

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Climate Change in Crete (4)

- ✓ Increase in the **maximum amount of precipitation within 24 hours & within 48 hours**, up to 20% (RCP8.5 scenario, long term horizon) in the northern coastal parts of the **Chania Prefecture**
- ✓ Lower increase in the **northern coastal parts** of the Municipalities of **Rethimno**, **Heraklion**, **Hersonissos** and **Agios Nikolaos**

➔ The above-mentioned areas will face a **greater risk of flooding in the future**.

Flash flood event following extreme precipitation in the coastal front of Gouves in the Municipality of Hersonissos (10/11/2020).

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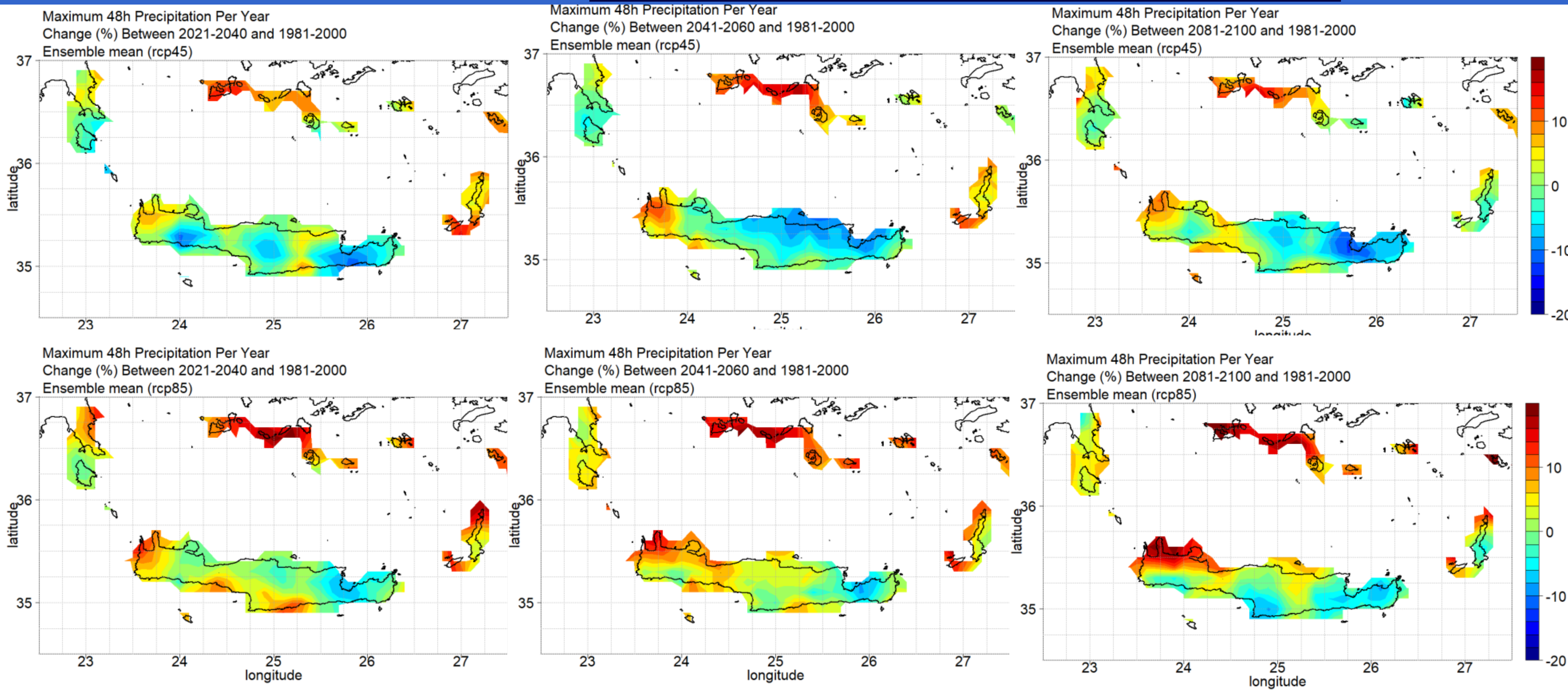
Climate Change in Crete

Change (%) of the 48-hour precipitation



Climate Change in Crete (5)

✓ **Reduction in days with total frost**

- They are expected to gradually become almost extinct even in the mountains (up to 1,500 m)
- Decrease of night frost (Tmin<0°C) in the future in all scenarios

✓ **Decrease of snow coverage in the coming decades (intermediate & worst-case scenario).** Time horizon 2081 – 2100, reduction up to 90% (worst-case scenario)

→ *The snow-covered areas will almost disappear in the whole of Crete up to at least 1,500m in the distant future.*

✓ **Sea level will rise in the future**

- Maximum rise value from 15cm (period 2021-2040) to 60-70 cm (long term), in the intermediate and worst-case scenario respectively
- The coastal areas of northern Crete are at greater risk (increase > 0.75 m in the worst-case scenario in the long-term time horizon)

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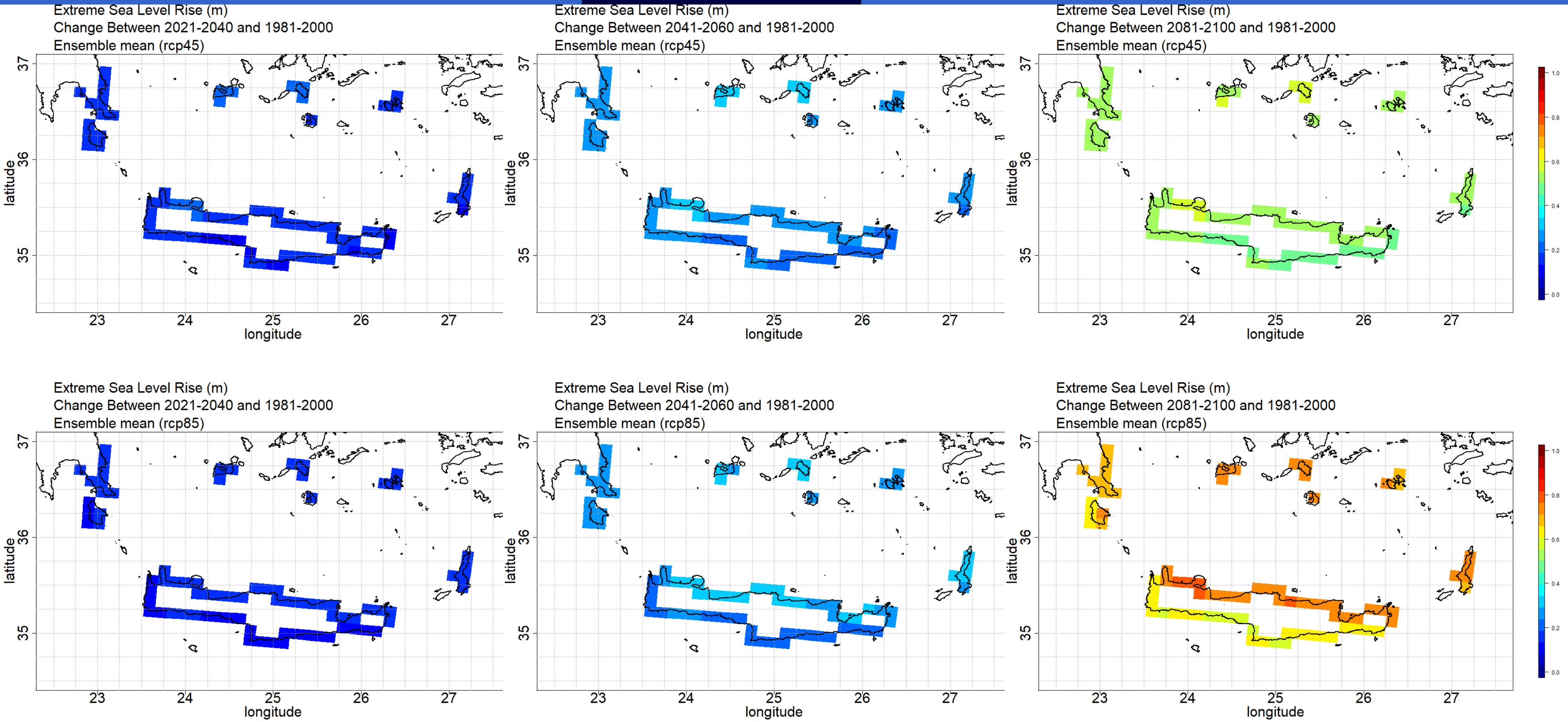
Climate Change in Crete

Sea level rise



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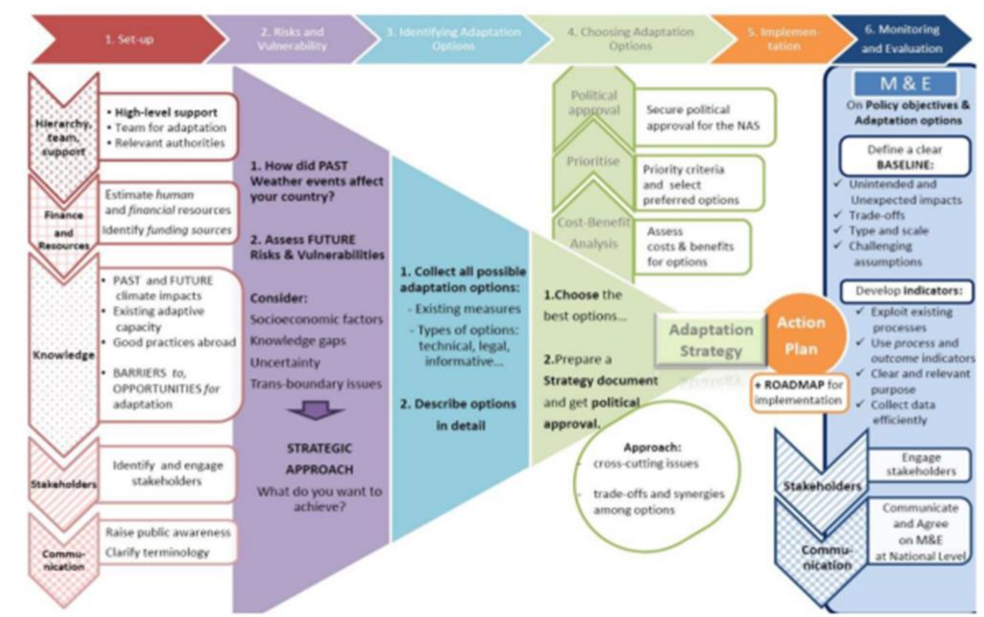
Vulnerability Assessment Methodology

STEP 1	**Selection of the sectors for which the vulnerability assessment will be performed**
STEP 2	Selection of the appropriate indices to evaluate the impact of each climate impact driver to each sector*
STEP 3	Sensitivity analysis of each sector to climate change
STEP 4	Exposure analysis for each sector to climate change
STEP 5	Vulnerability assessment of the different sectors and geographic areas



* The **climate impact drivers** for which the vulnerability assessment was carried under this assignment are:

- Temperature rise;
- Drought;
- Windstorms;
- Heat waves;
- Cold invasions / frost;
- Extreme precipitation;
- Snowcover decrease and
- Sea level rise.

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Sectors under evaluation

- **Agricultural and livestock production**
  - Agriculture
  - Livestock
- **Forests and Reforested Areas**
  - Forests
  - Reforested Areas
- **Biodiversity and Ecosystems**
- **Fisheries and Aquaculture**
  - Fisheries
  - Aquaculture
- **Water Resources** (availability of water resources)
- **Rivers** (flood events)

- **Coastal Zones**
- **Tourism**
- **Energy**
  - Energy Demand
  - Energy Infrastructure

- **Transport Infrastructure**
  - Road Network
  - Ports
  - Airports

- **Health**
- **Built Environment**
- **Cultural Heritage**

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Selection of the appropriate indices to evaluate the impact of each climate impact driver to each sector

Index	Climate Impact Driver	Sectors where it was used
Near-Surface Air Temperature change	Temperature rise	Farming, Protected Areas, Water Resources, Floods, Fisheries, Land Transport, Airports, Ports
Fire Weather Index (FWI) > 30 (high and very high risk of forest fire) change		Forests (fires), Forest Ecosystems
Summer daily maximum mean air temperature change		Tourism, Health
Cooling Degree Days (CDD) change		Energy Infrastructure, Industries, Health, Built Environment
Daily Maximum Near-Surface Air Temperature change		Livestock, Coastal Areas, Tourism, Energy Infrastructure, Industries, Built Environment, Cultural Heritage
Growing season change		Farming, Protected Areas, Forest Ecosystems
Days with Beach Climate Index (BCI) > 80 (excellent beach conditions) change		Coastal Areas, Tourism
Days with Tourism Climate Index (TCI) > 90 (ideal conditions for tourism) change		Tourism
Consecutive (duration) dry days – dry max spell change	Drought	Farming, Livestock, Forests (fires), Protected Areas, Water Resources, Floods, Tourism, Land Transport, Airports, Ports, Energy Infrastructure, Industries, Health, Built Environment, Cultural Heritage
Mean annual precipitation percent change		Farming, Livestock, Forests (fires), Protected Areas, Forest Ecosystems, Water Resources, Coastal Areas, Energy Infrastructure, Built Environment
Mean wind speed change during fire season (March – October)	Windstorms	Forests (fires)
Days with maximum wind speed > 10,8 m/sec (> 6 beaufort) change during summer		Forests (fires), Tourism
Days with maximum wind speed > 10,8 m/sec (> 6 beaufort) change		Farming, Livestock, Protected Areas, Forest Ecosystems, Fisheries, Coastal Areas, Tourism, Land Transport, Airports, Ports, Energy Infrastructure, Industries
Days with maximum daily mean air temperature > 30 °C change	Heat waves	Farming, Forests (fires), Protected Areas, Forest Ecosystems, Tourism, Land Transport, Ports, Energy Infrastructure, Industries
Humidex index > 37 (great discomfort) change		Tourism, Health, Built Environment
Tropical nights change		Livestock, Coastal Areas, Energy Infrastructure, Industries, Health, Built Environment, Cultural Heritage
Night frosts change	Cold invasions / frost	Livestock, Protected Areas, Land Transport, Airports, Built Environment
Total frosts (ice days) change		Farming, Forest Ecosystems, Tourism, Energy Infrastructure, Industries, Health
Consecutive days (duration) with minimum mean air temperature < -10 °C (cold spell) change		Farming, Livestock, Protected Areas, Forest Ecosystems, Tourism, Land Transport, Airports, Energy Infrastructure, Industries, Health, Built Environment
Maximum 5-day precipitation percent change	Extreme precipitation	Farming, Livestock, Protected Areas, Forest Ecosystems, Tourism, Land Transport, Airports, Ports, Health, Built Environment, Cultural Heritage
Maximum 1-day precipitation change		Farming, Livestock, Protected Areas, Forest Ecosystems, Tourism, Energy Infrastructure, Industries, Cultural Heritage
Days with precipitation value > 99th percentile of the historical period (extreme precipitation)		Water Resources, Floods, Coastal Areas, Land Transport, Airports, Ports, Energy Infrastructure, Industries, Health, Built Environment
Mean annual snowfall percent change	Snowfall decrease	Farming, Livestock, Water Resources, Land Transport, Airports, Energy Infrastructure, Industries, Built Environment, Cultural Heritage
Snowfall days change		Tourism, Health
Surface Snow Amount		Tourism
Sea level rise	Sea level rise	Farming, Livestock, Protected Areas, Forest Ecosystems, Water Resources, Floods, Fisheries, Coastal Areas, Tourism, Land Transport, Airports, Ports, Energy Infrastructure, Industries, Built Environment, Cultural Heritage
Storm surges		Protected Areas, Floods, Coastal Areas, Tourism

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Sensitivity Analysis

The purpose of this Step is to assess the sensitivity that is expected for every sector in each climate impact driver

The assessment in the context of the study was based on the feedback from the extensive stakeholders engagement that was performed and consultations that took place, and literature review (studies, papers etc. from Greek and international literature that focus on how climate change impacts the various sectors).

Based on the above information, we developed a sensitivity matrix for each sector and climate impact driver. Calculation of sensitivity was based on the following normalized scale:

- ✓ **Negligible sensitivity**: 0
- ✓ **Low sensitivity**: 1
- ✓ **Medium sensitivity**: 2
- ✓ **High sensitivity**: 3
- ✓ **Very high sensitivity**: 4

For example, water resources sector is very sensitive to droughts, due to reduced water supply and renewal of the aquifers, increased water demand, etc. compared to the fisheries sector which is not affected. Conversely, water resources are not affected by heat waves (they are practically influenced by the general temperature rise and not by temperature extremes), while the built environment sector is directly affected by heat waves (very sensitive)

Exposure Analysis

The climate indices selected and associated with climate impact drivers in Step 2, will be used to **describe the degree of exposure** of each grid point of the study area, to climate impact drivers, based on the following normalized scale:

- ✓ **Negligible exposure**: 0
- ✓ **Low exposure**: 1
- ✓ **Medium exposure**: 2
- ✓ **High exposure**: 3
- ✓ **Very high exposure**: 4

The approach for the correlation of each index change (i.e. change between the reference period and the short-term horizon in each RCP scenario) with the degree of exposure was presented in a matrix table. For example, a change in the near-surface air temperature (tas), compared to the reference period which is higher or equal to 4 ^{o}C, is considered to correspond to a very high degree of exposure, while a change between 1 and 2 ^{o}C, is considered to correspond to a medium degree of exposure.

Vulnerability Assessment

Vulnerability comes up as the function of sensitivity (Step 3) and exposure (Step 4).

Vulnerability = Sensitivity x Exposure

Vulnerability is assessed for each climate impact driver separately, but in the end the degree of vulnerability is overall assessed using the following normalized scale (in terms of past climate):

- ✓ **Negligible vulnerability**: ≤ 0.25
- ✓ **Low vulnerability**: 0.25 – 0.50
- ✓ **Medium vulnerability**: 0.50 – 1.00
- ✓ **High vulnerability**: 1.00 – 1.50
- ✓ **Very high vulnerability**: > 1.50

The vulnerability assessment was undertaken with **two approaches**:

- **Geographic vulnerability**: Investigates the geographic areas for each sector that are most vulnerable to climate change. In this case, vulnerability was calculated only for the grid points which belong to the sector under investigation.
- **Sectoral vulnerability**: Investigates the sectors of the natural and anthropogenic environment that are most vulnerable to climate change and to which priority should be given to measures and actions. In this case, the sectoral vulnerability is the average vulnerability value of the grid points that correspond to geographic areas of the sector.

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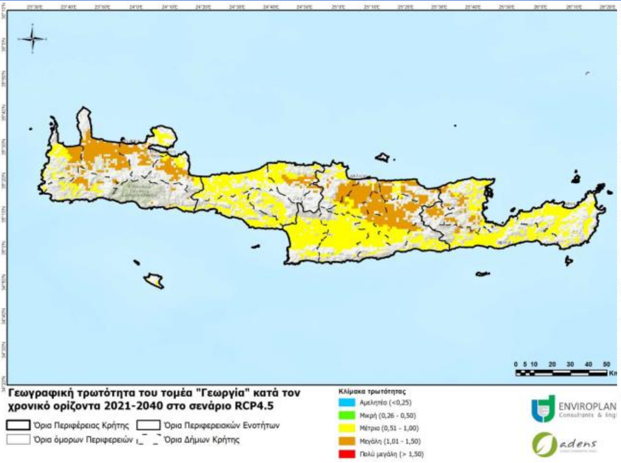
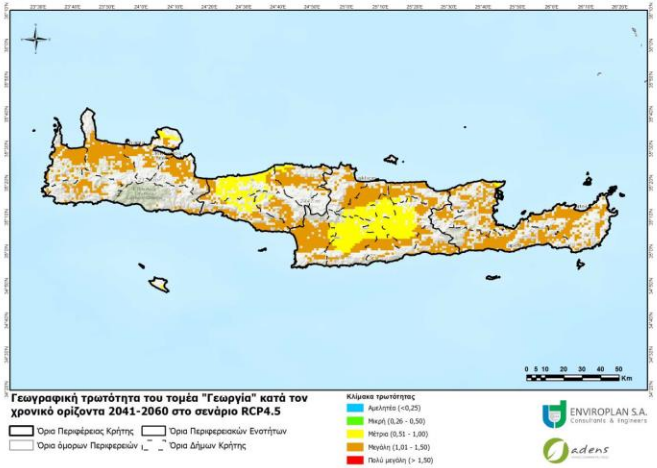
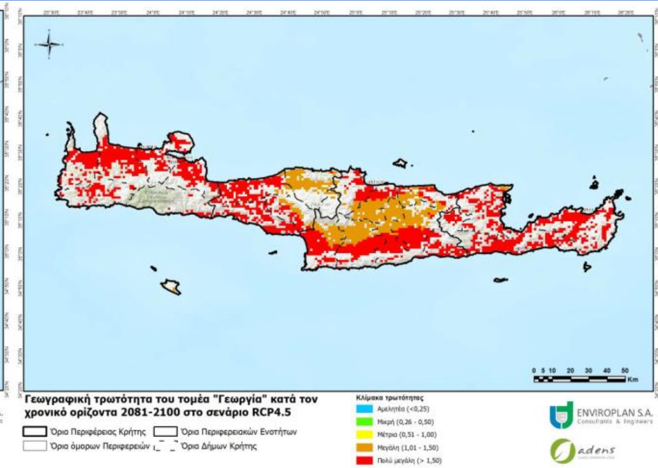
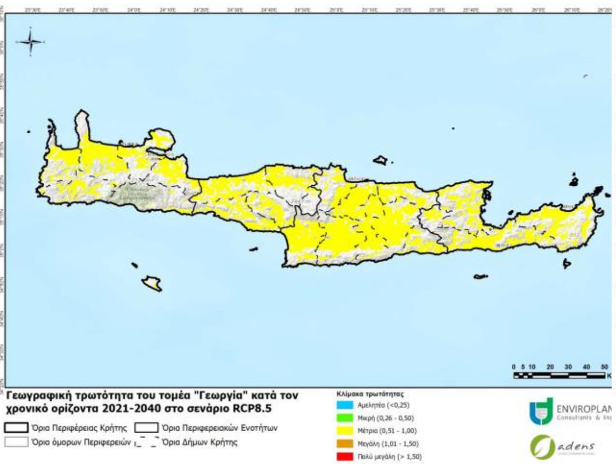
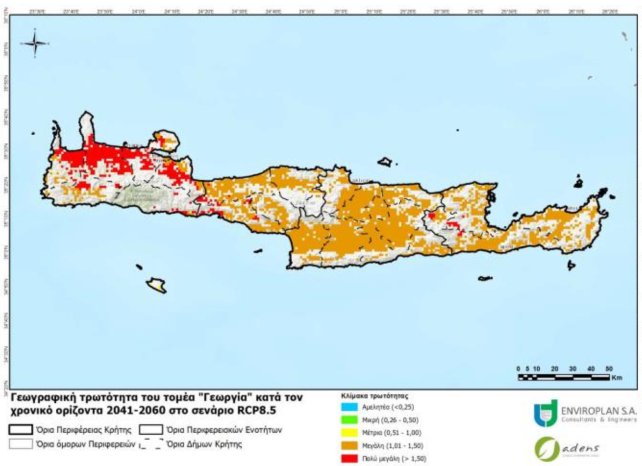
The case of a vulnerable sector - Agriculture

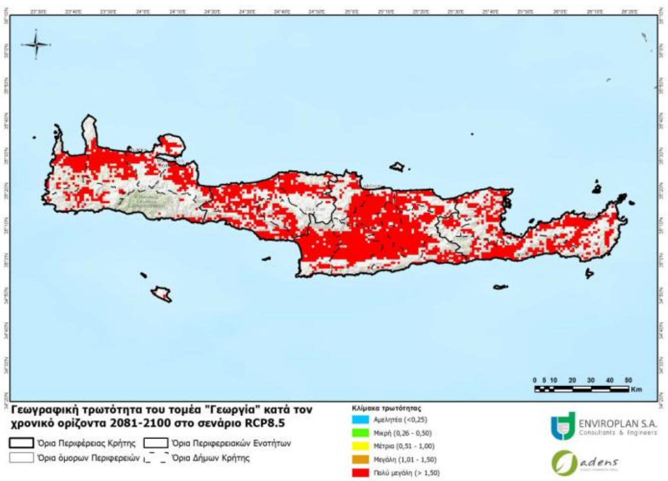












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Key impacts of climate change

- Reduction of available **water reserves**
- Increased **fire risk**
- Reduction in annual **agricultural production**, shift to less water-intensive crops
- Reduction of **soil fertility**, aggravation of the phenomenon of **desertification**
- Changes in the growth rate of **flora species**
- Increased presence of **pests & diseases**
- Increase in occurrence of **flooding events**
- Increase in river/stream **stereosupply**, ecological disturbance of water bodies in estuaries
- Increase in **erosion** phenomena
- Increased risk of **landslides**
- Changes in **habitats** & **availability of food and water** for animal species
- Increase of **eutrophication**, growth of harmful algae

Key impacts of climate change

- **Migration** of marine species, **invasion of alien species**
- Reduction in **fishing production**
- Impacts on systems and methods of **aquaculture activity**
- Causing partial or total disasters in **sensitive historical monuments** / **archaeological sites** (directly exposed to environment & weather events)
- **Coastal erosion** – coastal floods
- Entry of **salt water** into habitats, transitional waters & river estuaries
- Increase in citizens' **discomfort**
- Increased **incidence of diseases** (asthma, allergies, cardiorespiratory problems, etc.)
- Increase **in demand / energy consumption** for air conditioning in the summer months
- **Erosions of road slopes**, subsidence of pavements

Measures assessment and prioritization

The proposed measures were assessed and prioritized based on the following criteria:

- **Effectiveness** (Avoidance of impacts, reduction of intensity, restoration)
- **Implementation bodies**
- **Funding sources**
- **Priority based on vulnerability** (1st priority, 2nd priority)
- **Implementation period** (maturity or assignment time and implementation horizon)
- **Indicative budget**
- **Benefit (financial, environmental, social)** (high, moderate, low)
- **Cost / Effectiveness Ratio** (low, medium, high)

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Measures implementation cost

Per sector

Sector	Number of Measures	Cost per Sector	Distribution of Cost
HORIZONTAL MEASURES	6	20.500.000,00	6,93%
AGRICULTURE	28	**43.290.000,00**	**14,64%**
LIVESTOCK	9	10.050.000,00	3,40%
FORESTS	11	8.020.000,00	2,71%
REFORESTED AREAS	9	2.930.000,00	0,99%
BIODIVERSITY - ECOSYSTEMS	16	5.850.000,00	1,98%
FISHERIES	12	3.670.000,00	1,24%
AQUACULTURE	8	1.365.000,00	0,46%
WATER RESOURCES (AVAILABILITY)	17	**35.250.000,00**	**11,92%**
RIVERS (FLOOD EVENTS)	14	**46.500.000,00**	**15,72%**
COASTAL ZONES	10	**25.850.000,00**	**8,74%**
TOURISM	11	6.700.000,00	2,27%
ENERGY DEMAND	5	**25.400.000,00**	**8,59%**
ENERGY INFRASTRUCTURE	8	11.475.000,00	3,88%
TRANSPORT INFRASTRUCTURE	19	20.780.000,00	7,03%
HEALTH	16	6.650.000,00	2,25%
BUILT ENVIRONMENT	20	17.750.000,00	6,00%
CULTURAL HERITAGE	8	3.700.000,00	1,25%
TOTAL	**227**	**295.730.000,00**	**100,00%**

Per measure type

Measure Type	Number of Measures	Cost per Category	Distribution of Cost
ADMINISTRATIVE ARRANGEMENTS	22	0,00	0,00%
STUDIES	69	**28.720.000,00**	**9,71%**
RESEARCH AND PILOT ACTIONS	14	10.970.000,00	3,71%
PUBLIC WORKS	48	**173.770.000,00**	**58,76%**
EQUIPMENT PROVISION	5	17.500.000,00	5,92%
MONITORING	17	11.650.000,00	3,94%
ALERT SYSTEMS	7	7.500.000,00	2,54%
COMMUNICATION MEASURES	20	1.320.000,00	0,45%
FINANCIAL INCENTIVES	17	32.300.000,00	10,92%
REFUNDS	8	12.000.000,00	4,06%
TOTAL	**227**	**295.730.000,00**	**100,00%**

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Monitoring of the Plan

In order to effectively monitor the implementation progress of the Plan, an appropriate monitoring mechanism has been proposed. It will be coordinated by the Climate Change Department of the Region of Crete.

Relies on two key tools:

- **Data Collection Network (Observatory of Climate Change)**
- **Monitoring Indices**
  - ✓ Monitoring of Climate Change Indices
  - ✓ Indices of the Implementation of Measures
  - ✓ Indices for the Evaluation of the Results from the Implementation of Measures

In addition to the creation of a Department of Climate Change, in order to achieve the desired results of the measures undertaken in the context of the implementation of the Plan, the establishment of a **Regional Committee for Combating Climate Change (PEAKA)** was proposed and will be implemented.

Thank you for your attention!

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