Developing a Regional Climate Change Adaptation Plan for Island Regions. The case of South Aegean Region in Greece.

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ABSTRACT

The overall purpose of the Regional Adaptation Plan to Climate Change (RAPCC) of the South Aegean Region (SAR) is to contribute to enhancing the region's resilience to climate change in all sectoral policies as outlined in the National Climate Change Adaptation Strategy. This means increasing preparedness and capacity to address the impacts of climate change at local and regional level, developing a coherent approach and improving coordination.

The methodology used to assess the climatic vulnerability of the individual sectors and geographical areas of the SAR and ultimately the climate risk assessment comprised nine solid steps beginning from defining “reference" changes of climatic variables to assess the vulnerability of the different activities and ending with ranking sectors and activities as to the magnitude of the risk. The analysis of the climatic vulnerability and danger and hence risk of the different sectors and activities of the South Aegean Region was carried out for the short and medium term (2021-2050) and long-term horizons (2071-2100) and distinct for the geographical units of Cyclades and Dodecanese.

According to these findings the proposed measures in the RAPCC were based on island specific characteristics such as financial-social activities, geomorphology and developed both in horizontal and sectoral actions and classified into High, Medium and Low priority.

INTRODUCTION

The Regional Adaptation Plan to Climate Change (RAPCC) of the South Aegean Region (SAR) is compiled in the framework of the obligations and specifications deriving from the relevant national legislation (L.41414 / 2016 and MD 11258/2017). The South Aegean Region is a border region at national and European level. Its main characteristic is its wholly islandic environment as it consists of two large island groups, the Cyclades and the Dodecanese. Its geographic position in the southeast basin of the Mediterranean places it according to the 4th Report of the Intergovernmental Panel on Climate Change [6] in those areas characterized as vulnerable to climate change.

The Region's economy relies heavily on the tertiary sector and particularly on the services sector. According to Eurostat [5], the Region of South Aegean is the first at national and pan-European level in the statistical index "overnight stays in hotel accommodation relative to the size of the population (per 1000 inhabitants)" approaching 69.777. Moreover, much of the Region, both the Cyclades and the Dodecanese, has been recognized by the scientific community as ecologically important. This is a total of 31 sites proposed for inclusion in the NATURA 2000 network [8], 39 Corine Habitats as a whole, and a significant number of wetlands recorded at the Greek wetland sites of the Greek Biotope/Wetland Centre.

Fig.1: Map of the South Aegean Region

The project aims to record short-, medium- and long-term assessments of climate change in the South Aegean Region, to assess the immediate and future environmental, economic and social impacts of climate change on fifteen economic sectors of the Region and to evaluate (both environmentally and socio-economically) the possible adaptation actions in these areas. The fifteen sectors for which Sectoral Adaptation Policies have been developed in the scope of the RAPCC are (1) Agriculture and livestock farming, (2) Forests, (3) Biodiversity and ecosystems, (4) Fisheries, (5) Aquaculture, (6) Water resources, (7) Coastal zones, (8) Tourism, (9) Energy, (10) Infrastructure and Transport, (11) Health, (12). Built environment, (13) Extractive industry, (14) Cultural heritage and (15) Insurance sector.

The proposed adaptation measures pillars and policy priorities of the RAPCC were connected to the objectives of the National Climate Change Adaptation Strategy [10] according to the following table.

Table 1: Correlating the Pillars-Policy Priorities RPACC of SAR with National Climate Change Adaptation Strategy Objectives

National Climate Change Adaptation Strategy Objectives	**Pillars- Policy Priorities RAPCC**		
	Leadership and Enhancement of Administrative Capacity	**Promote and diffuse knowledge & skills**	**Strengthening Resilience in Priority Areas**
Systematization and improvement of the decision-making process (short and long-term)	√	√	
Connecting adaptation with promoting a sustainable development model through regional / local action plans	√	√	√
Promoting actions and adjustment policies in all sectors of the economy, focusing on the most vulnerable	√		√
Establishment of a mechanism for monitoring, evaluating and updating adaptation actions and policies	√	√	√
Strengthening the adaptive capacity of Greek society through information and awareness actions		√	

MATERIALS AND METHODS

The South Aegean Region is divided into two distinct climatic regions, those of Cyclades (CY) and Dodecanese (D) [1]. Climate change assessment, analysis of its impact on various sectors as well as vulnerability analysis of the South Aegean Region require climate data with the greatest possible spatial and temporal analysis. The data used cover a period of 30 years for the current climate (1961-1990) and two 30-year periods for the future climate (2021-2050 mid-term and 2071-2100 long term) as the analysis in the CCISC and are the results of the application of the regional climatic model $RACMO_{2.2}$ of KNMI with a 0.11^{o} special resolution, in conjunction with the global climatic model EC-EARTH based under the RCP4.5 (GHG stabilization) and RCP8.5 (GHG growth) scenarios in the scope of the EURO-CORDEX project [7].

Climatic parameters accessed were mean daily values of (1) air temperature, (2) relative humidity, (3) cloud cover fraction, (4) sunshine duration, (5) wind speed, (6) precipitation. In addition, to estimate the frequency and intensity of extreme weather events, the following climatic indicators were also accessed:

- changes of average minimum and maximum temperatures
- number days per year with a maximum daily temperature > 35^{o}C (heat waves)
- number of days of discomfort (computed with HUMIDEX Index)
- number days per year with a minimum temperature < 0^{o}C (night frost)
- maximum hourly precipitation per year
- number of days with increased risk of forest fires computed with the FWI-Forest Weather Index-System[12].

The methodology used to assess the climatic vulnerability of the individual sectors and geographical areas of the South Aegean Region and ultimately the climate risk assessment was similar to other notable relevant studies [11] and EU recommendations [2] and comprised the following steps:

1. Definition of "reference" changes of climatic variables to assess the vulnerability of the different activities in light of the maximum expected variations from the results of the scenarios.
2. Identification of business processes and operational parameters per activity affected by the change in the climatic parameters
3. Definition of a scale of impacts based on the operational parameters per activity.
4. Vulnerability per activity in the event of the "reference" climate parameter changes.
5. Estimation of potential vulnerability reduction due to the possibility of adaptation.

6. Estimation of the magnitude of expected changes per time period (2 periods, 2021-2050 and 2010-2100) and per scenario (2 scenarios, RCP4.5 and RCP8.5)
7. Assessment of the danger of the climatic changes from the model estimates in relation to the respective "reference" ones
8. Risk assessment by sector and activity by combining vulnerability and danger.
9. Ranking sectors and activities as to the magnitude of the risk

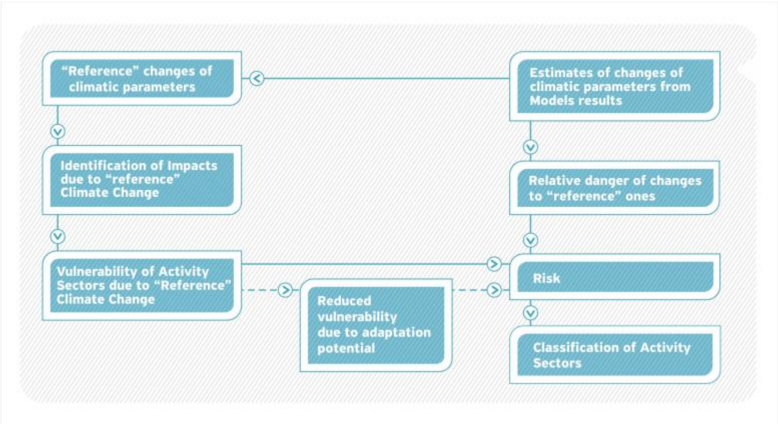

Fig.2: Summary presentation of the climate hazard assessment methodology for the South Aegean Region

The first step (I) of the methodology, as shown in the figure above, was the definition of the "reference" climate change to assess the climatic vulnerability of a sector or activity.
As a "benchmark" climate change, extreme values were selected from the overview of published estimates for the Mediterranean region as well as the results of climate simulations for all periods and scenarios.

Table 2: Benchmark climate parameters values for the definition of the reference climate change

Parameters (difference from today's conditions)	**Unit**	**Maximum Value**	**Definition of change for the climate parameters**			
Temperature			**Small**	**Medium**	**High**	**Extreme**
Mean	**Δ°C**	**4**				
Mean Maximum	**Δ°C**	**8**	**0.5 < Δ <1**	**1 < Δ < 2**	**2 < Δ < 4**	**Δ > 4**
DegreeDays net (Heating – Cooling)	**Δ Growing DegreeDays.**	**1000**	**1 < Δ <2**	**2 < Δ < 4**	**4 < Δ < 6**	**Δ > 6**
Forest Weather Index (FWI)	**Δ FWI**	**50**	**Δ < 250**	**250 < Δ < 500**	**500 < Δ < 750**	**Δ > 750**
Tourist Climate Index (TCI) months with high demand	**Δ TCI**	**20**	**< 10**	**10 < Δ < 20**	**20 < Δ < 30**	**Δ > 30**
Drought						
Mean Annual Precipitation	**Δ %**	**25**	**3 < Δ < 5**	**5< Δ < 10**	**10 < Δ < 15**	**Δ > 15**
Days with precipitation <1mm	**Δ days**	**40**	**3 < Δ < 10**	**10 < Δ < 20**	**20 < Δ < 30**	**Δ > 30**
Wind						
Mean Speed	**Δ m/s**	**3**	**< 0.5**	**0.5 < Δ < 1.0**	**1.0 < Δ < 1.5**	**Δ > 1.5**
Days with maximum wind speed >10.8m/s	**Δ days**	**40**	**5 < Δ < 10**	**10 < Δ < 20**	**20 < Δ < 30**	**Δ > 30**
Heat waves						
Days with maximum T >35°C	**Δ days**	**30**	**3 < Δ < 10**	**10 < Δ < 15**	**15 < Δ < 20**	**Δ > 20**
Days with Humidex > 38	**Δ days**	**40**	**5 < Δ < 10**	**10 < Δ < 20**	**20 < Δ < 30**	**Δ > 30**
Cold invasions and Frost						
Days with minimumT < 0 °C	**Δ days**	**60**	**Δ < 10**	**10 < Δ < 30**	**30 < Δ < 50**	**Δ > 50**
Rainfall and Snowfall						
Two days height of precipitation	**Δ%**	**40**	**Δ < 10**	**10 < Δ < 20**	**20 < Δ < 30**	**Δ > 30**
Decrease of snowfall height	**Δ%**	**40**	**5 < Δ < 10**	**10 < Δ < 20**	**20 < Δ < 30**	**Δ > 30**
Increase of sea level						
Sea Level	**Δmm**	**100**	**20 < Δ < 35**	**35 < Δ < 50**	**50 < Δ < 100**	**Δ > 100**
Surges						
Increase of maximum height	**Δ %**	**50**	**10 < Δ < 20**	**20 < Δ < 30**	**30 < Δ < 50**	**Δ > 50**

For the assessment of vulnerability, as shown in Fig. 2, the second step (II) was to identify the processes and functional parameters of the sectors and activities affected by the change in climatic parameters and the effects of climate change (Table 3).

Table 3: Impacts on activities occurring in the South Aegean Region affected by changes in climatic parameters and basic operational parameters based on changes in which the magnitude of the impact is estimated.

Impacts of Changes in Climatic Parameters			
Activity (by NACE Classification)	**Main Impact**	**Operative Parameter**	**Units**
Primary Sector (A, B)			
Agriculture, Forestry and Fishing (A)	Production	Yearly Production	**%**
Fisheries, Aquaculture (A)	Fish stock	Yearly Production	**%**
Forestry (A)	Fires/Diseases	% area in danger	**%**
Mining and Quarrying (B)	Water and power availability	Yearly Production	**%**
Manufacturing €			
	Facilities/ Working conditions	Yearly Revenues	
Electricity, Gas, Steam & A/C Supply (D)			
Thermal Power Units	Power/Production efficiency	Yearly Production	**%**
Wind	Capacity factor	Yearly Production	**%**
Hydro Power	Water supply	Yearly Production	**%**
Photovoltaics	Capacity factor	Yearly Production	**%**
Energy Demand	Heating/Cooling/Losse	Consumption	**%**
Water Supply; Sewerage, Waste Management and Remediation Activities (E)			
Irrigation	Irrigation resources	Water resources	**%**
Water Supply	Drinking water resources	Water resources	**%**
Sewage & Waste Management	Flooding	Serice interuption	**%**
Transport and Storage (H)			
Road Transport	Flooding/Damage/Deterioration	% km under risk	**%**
Rail	Flooding/Damage	% km under risk	**%**
Aviation	Lifting reduction / Deterioration	People/Goods activity	**%**
Ports	Docks/ Wave height	People/Goods activity	**%**
Built Environment (E, F, L, Q, R)			
Construction (F)	Structure Deterioration/Flooding	Repair costs per building	**%**
Historic City Centers €	Discomfort	Humidex > 37 increase	**%**
Cultural Heritage Sites & Buildings ®	Structure Deterioration/Flooding	Restoration value	**mil€**
Hospitals, Health Service Facilities (Q)	Facility deterioration/Flooding	Operational ability reduction	**%**
Sewage & Waste Management €	Flooding/Fires	Numbers	**N**
Accommodation and Food Service Activities (I)			
Winter and Ski Resorts	Snow fall	Snowfall amount	**%**
Summer Tourism	Attractiveness	Reduction of visits	**%**
Tertiary Sector (G, K, M, N, O, P, R, S)			
Financial & Insurance Activities (K)	Damages	Yearly Revenues	**%**
Professional, Scientific & Techical Activities (M)	Working Conditions	Yearly Revenues	**%**
Arts, Entertainment and Recreation ®	Working Conditions	Yearly Revenues	**%**
Wholesale & Retail Trade (G)	Working Conditions	Yearly Revenues	**%**
Other Service Activities (S)	Working Conditions	Yearly Revenues	**%**
Education (P)	Operating Conditions	Operating days reduction	**%**
Administrative & Support Service Activies (N)	Work load/working conditions	Services	**%**
Public Administration and Defence (O)	Work load/working conditions	Services	**%**
Human Health and Social Work Activities (Q)			
Population/Vulnerable Groups	Health Effects	Morbitidy/100K	**%**
Population	Environmental Conditions	Humidex > 37 Ημερες %	**%**
Coastal Regions			
Internal Water Bodies	Shore conditions/ Water quality	% Reduction of water	**%**
Beaches	Flooding	% Area in danger	**%**
Biodiversity and Nature			
Wetlands	Drought	% Area in danger	**%**
Landscapes of Natural Beauty	Deterioration	% Area in danger	**%**
Marine Environment	Acidity	pH (CO_2)	**N**
Atmosphere	Quality (SOX, NOX, SP)	Pollutant Concentration	**Conc%**

The selection of sectors and activities of SAR likely to be threatened by the Climate Change was based on ELSTAT's [4] classification for the national economy but was also complemented by the additional categories beyond the economic dimension of the Natural Environment, Structured Environment, Cultural Heritage and Society.

The next steps (III &IV) of the methodology, as shown in Fig.2, was to estimate the vulnerability of each sector and activity in the event of occurrence of "reference" changes in the climatic parameters.

Vulnerability assessment is based on:

- Activity-specific quantitative and qualitative assessments of Greek and international literature on the "sensitivity" of each sector and activity to climate change
- Internal risk assessments reported in annual reports of business executives as well as in
- Expert's judgment of project team members

In addition to the "sensitivity" of each sector, the probability of the occurrence and geographical extent of climate change, the size of the affected population, and the complexity and interactions of phenomena are taken into account.

Human intervention in the above areas can facilitate adaptation to climate change, limiting its negative impacts (e.g. by implementing preventive fire protection measures in the case of forest fires). Therefore, the next step (V) in the methodology is to assess the potential reduction in vulnerability due to the existing capability of adaptation.

The actual intensity of each climatic parameter according to the following figure, as derived from its values according to the results of the numerical models over a period of time, geographical area and scenario, is used for the risk assessment (Step VI).

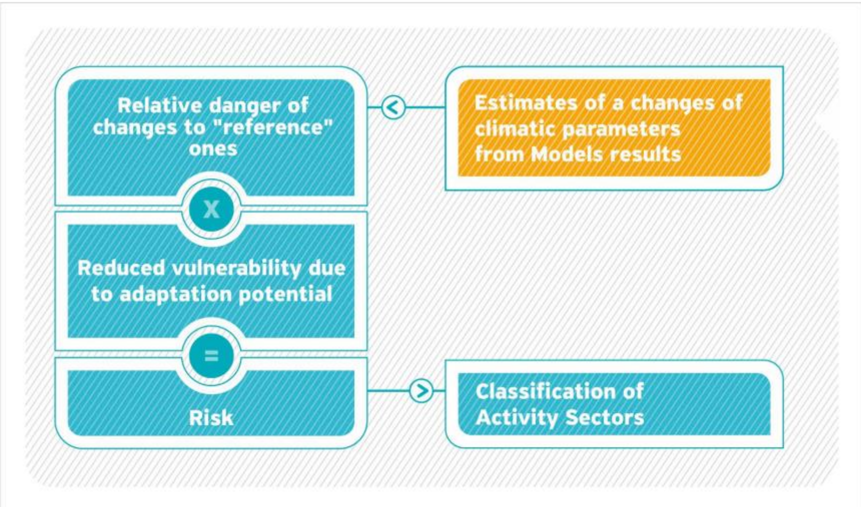

Fig.3: Step VI describes the calculation of the sectoral risk and the classification of sectoral activities

In the next step (VII), each activity is rated in terms of the risk of each climatic parameter (expressed by the most activity-related element if there are more than one), essentially as the percentage of calculated values of a parameter in relation with the reference value "on the basis of which the" reference "vulnerability has been assessed. The risk is also expressed in a 5-point scale (negligible, small, medium, long, extreme from 0 to 4).

The climatic risk for each activity is calculated as the product of "standard" vulnerability to the risk for each climatic variable (Step VIII).

Finally (Step IX), by combining all the risk assessments for the two scenarios, the two periods and the two geographical areas (Cyclades and Dodecanese), one can estimate the overall risk of each activity / sector so that it is able to identify sectoral spatial and geographical priorities for adaptation actions.

RESULTS

The following table summarizes the average values of the key climatic parameters in selected representative islands of the Southern Aegean Region for the 1961-1990, 2021-2050 and 2071-2100 periods based on the results of the RACMO2.2 climatic simulations for the RCP4.5 and RCP8.5 scenarios. The islands that have been selected are locations for which weather data are available from the National Meteorological Service for at least the last 25 years and include the largest islands of Cyclades (Naxos) and Dodecanese (Rhodes, Kos) as well as islands representative of the southern (Karpathos and Thira) and the western areas (Milos) of the Region. For completeness and coverage of the entire area of the SAR, and although there are no climatic data available, the analysis includes an island of the northern Cyclades (Tinos) and one of the northern Dodecanese (Patmos).

According to climate models analysis, the Dodecanese islands of Karpathos and Rhodes will face the higher temperatures for both RCP8.5 and RCP4.5 scenarios up to the end of the century. On the other hand Karpathos and Santorini will have the lower level of precipitation for both scenarios. The analysis of wind speed showed less significant changes. Tinos from Cyclades and Patmos island from Dodecanese had the higher values of wind speed. In terms of relative humidity Santorini and Milos from Cyclades had the highest values until 2100 and Rhodes and Kos (from Dodecanese) the lowest. No significant changes were observed for Cloud cover fraction and sunshine duration. However, Milos and Santorini from Cyclades had the highest cloud cover fraction and finally Patmos from Dodecanese and Tinos from Cyclades the highest mean values of sunshine duration.

Table 4: Mean air temperature at 2m, total precipitation, snowfall, relative humidity, wind speed of 10m, relative humidity, cloud cover fraction and sunshine duration at selected representative islands of the Region for the 1961-1990, 2021-2050 and 2071-2100 according to the results of climatic simulations with the regional model RACMO2. 2 for the RCP4.5 and RCP8.5 scenarios.

	1961-1990	2021-2050		2071-2100	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
Mean Air Temperature 2 m (ºC)					
Rhodes	16.61	17.82	18.16	18.74	20.24
Kos	16.42	17.54	17.89	18.46	19.81
Naxos	15.44	16.56	16.91	17.49	18.80
Santorini	16.51	17.58	17.90	18.48	19.68
Karpathos	17.16	18.24	18.54	19.11	20.36
Milos	16.33	17.42	17.75	18.34	19.56
Tinos	15.69	16.79	17.12	17.72	18.94
Patmos	16.23	17.33	17.66	18.25	19.51
Mean values of total annual precipitation (mm)					
Rhodes	625.6	592.3	589.9	567.4	463.2
Kos	606.9	605.0	590.7	580.2	479.1
Naxos	516.0	517.0	514.7	497.1	426.3
Santorini	434.5	444.0	418.5	424.0	350.9
Karpathos	409.3	399.6	378.2	376.4	312.3
Milos	481.9	477.6	452.3	471.4	394.2
Tinos	503.41	498.21	504.09	485.23	422.73
Patmos	577.31	574.71	564.50	560.27	478.89
Mean wind speed at 10 μ. (m/s)					
Rhodes	5.34	5.43	5.35	5.39	5.14
Kos	6.77	6.95	6.85	6.90	6.87
Naxos	6.53	6.71	6.67	6.66	6.71
Santorini	7.26	7.41	7.36	7.36	7.32
Karpathos	7.07	7.30	7.21	7.25	7.31
Milos	7.32	7.42	7.40	7.34	7.35
Tinos	7.85	8.02	7.99	7.95	8.03
Patmos	7.24	7.44	7.38	7.39	7.41
Mean values of relative humidity (%)					
Rhodes	70.7	70.2	70.2	70.3	69.8
Kos	71.5	71.2	71.1	71.3	71.2
Naxos	73.4	73.1	73.1	73.1	73.1
Santorini	73.7	73.5	73.5	73.5	74.1
Karpathos	72.6	72.6	72.6	72.6	73.2
Milos	73.5	73.2	73.2	73.1	73.6
Tinos	74.4	74.1	74.2	74.0	74.5
Patmos	72.7	72.6	72.5	72.6	72.9
Mean values of cloud cover fraction (%)					
Rhodes	29.5	27.2	27.6	27.0	24.6
Kos	30.6	28.6	29.2	28.8	26.7
Naxos	33.5	32.0	32.0	31.8	29.1
Santorini	33.9	32.5	32.3	32.4	29.8
Karpathos	33.5	31.7	31.6	31.9	28.6
Milos	34.9	33.5	33.2	32.9	29.8
Tinos	32.7	31.5	31.4	31.0	28.4
Patmos	30.1	28.5	29.0	28.6	26.5
Mean values of sunshine duration (hours/day)					
Rhodes	9.35	9.46	9.42	9.47	9.56
Kos	9.39	9.45	9.43	9.46	9.52
Naxos	9.23	9.29	9.29	9.28	9.39
Santorini	9.39	9.42	9.45	9.41	9.51
Karpathos	9.31	9.37	9.37	9.35	9.45

	1961-1990	2021-2050		2071-2100	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
Milos	9.25	9.30	9.33	9.32	9.46
Tinos	9.43	9.47	9.47	9.48	9.57
Patmos	9.50	9.56	9.51	9.54	9.60

Temperature

Climate simulations based on both scenarios of evolution of GHG concentrations show as a general result the increase in average air temperature across the South Aegean Region, as shown in the following maps. Based on the RCP4.5 Scenario in the period 2021-2050 the average annual temperature is expected to increase in the Region by 1.0-1.2 °C and 1.9-2.2 °C in the period 2071-2100 relative to the historical climate of the period 1961-1990. Respectively, based on the unfavorable RCP8.5 scenario, the temperature will be higher by 1.5°C in the period 2021-2050 and 3.0-3.6°C in the period 2071-2100. In both scenarios, the rise in temperature is greatest in the Dodecanese islands, especially in Rhodes, and in the Northern Cyclades and less in the other islands of the Cyclades.

On a seasonal basis in the period 2021-2050, the highest temperature increase compared to the historical climate in both scenarios is expected mainly in the spring months, while the lower rise in autumn. Similarly, in the period 2071-2100, higher temperature increases are expected in the winter and autumn months and less in the summer and spring months.

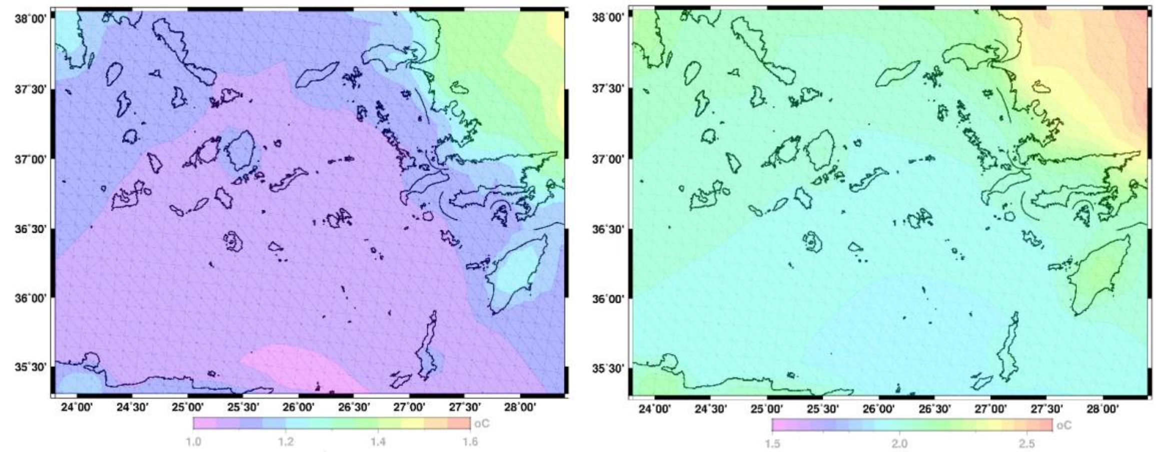

Fig.4: Changes in the mean air temperature to 2 m (° C) between the periods 2021-2050 and 1961-1990 (left), 2071-2100 and 1961-1990 (right) according to the results of the climatic simulations with the regional model RACMO2.2 for the RCP4.5 scenario

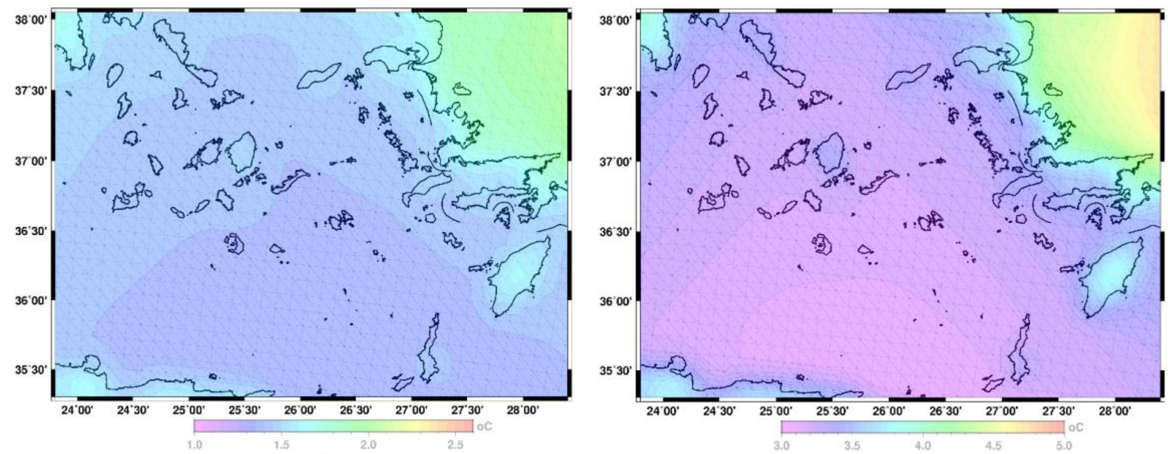

Fig.5: Changes in the mean air temperature to 2 m (° C) between the periods 2021-2050 and 1961-1990 (left), 2071-2100 and 1961-1990 (right) according to the results of the climatic simulations with the regional model RACMO2.2 for the RCP8.5 scenario.

Precipitation

The reduction in annual precipitation is expected to be particularly significant in the case of the RCP8.5 scenario and milder in the case of the RCP4.5 scenario. In the case of the mild RCP4.5 scenario, a reduction in precipitation of up to 5% over the period 2021-2050 and 10% over the period 2071-2100 in the Region as a whole is envisaged. In the case of the unfavorable RCP8.5 Scenario, significant reductions in annual precipitation are expected in almost the entire region. The expected reductions in the period 2021-2050 are projected to increase by up to 8% compared to the period 1961-1990, while they are expected to be higher at the end of the 21st century, as between 2071-2100 they will exceed 20% almost the area of the Region. The largest percentage declines in annual precipitation are predicted in both scenarios of the Dodecanese islands, which have historically recorded higher precipitations than those of the Cyclades islands.

On a seasonal basis, in the case of the unfavorable RCP8.5 Scenario, the largest decline in both absolute and percentage magnitude is expected in the autumn months for both periods and across the Region.

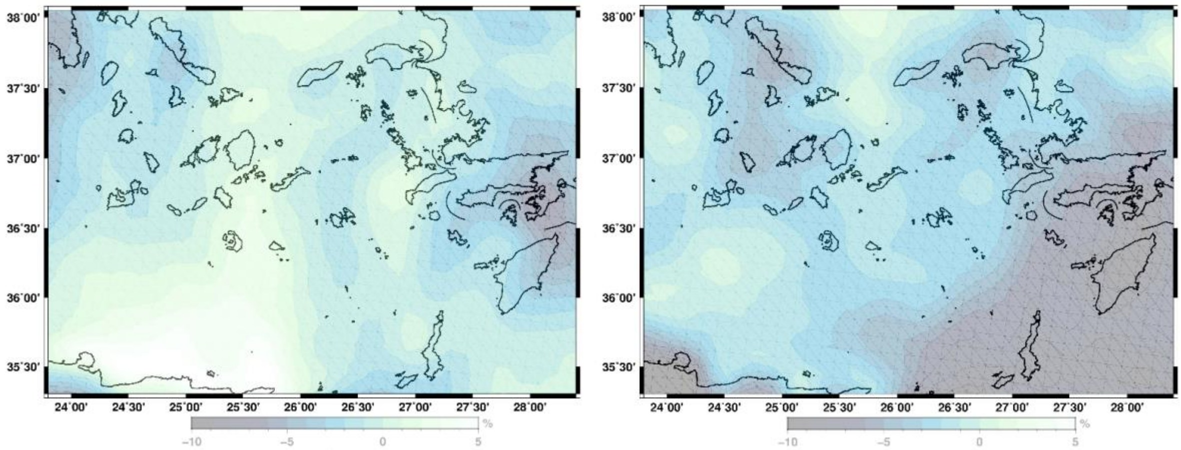

Fig.6: Percentage changes in the mean annual precipitation between 2021-2050 and 1961-1990 (left), 2071-2100 and 1961-1990 (right) according to the results of climatic simulations with the regional model RACMO2.2 for the RCP4.5 scenario

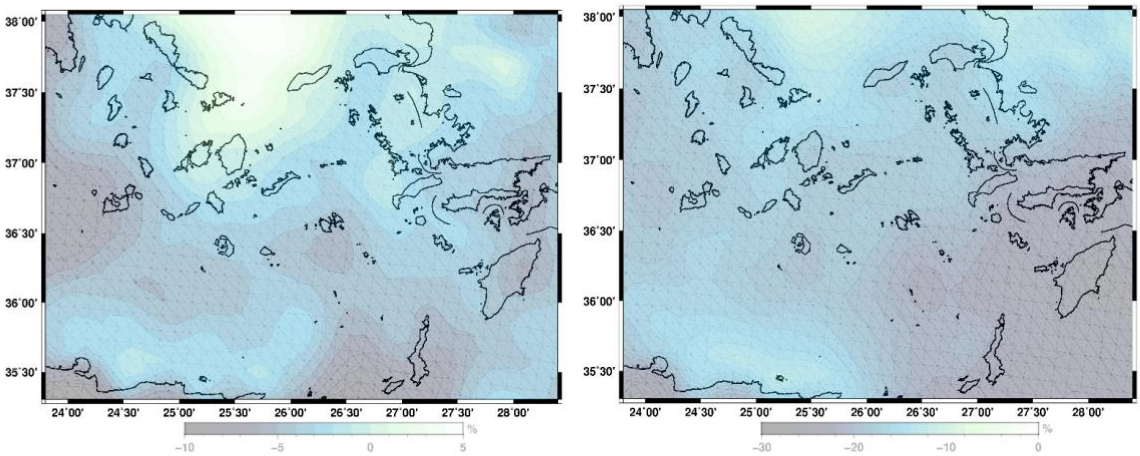

Fig.7: Percentage changes in the mean annual precipitation between the periods 2021-2050 and 1961-1990 (left), 2071-2100 and 1961-1990 (right) according to the results of climatic simulations with the regional model RACMO2.2 for the RCP8.5 scenario

Wind Speed

The average wind speed at Regional level is not expected to change significantly in both scenarios of GHG concentrations. In the RCP4.5 scenario, a slight increase in the average annual wind speed of up to 4% is expected over the entire area of the Region in both future periods. In the RCP8.5 scenario, the increase in average annual wind speed is lower than the RCP4.5 scenario, while in the Rhodes region a slight decrease is expected in the period 2071-2100.

Relative Humidity

According to the results of the climate simulations, a significant change in the average annual relative humidity relative to the historical climate of the period 1961-1990 is not expected across the South Aegean Region since these changes are close to 1%.

Cloud cover fraction and Sunshine duration

The results of climate simulations show a decrease in cloud cover and a slight increase in the duration of sunshine throughout the South Aegean Region and in the two scenarios for the evolution of GHG concentrations.

The trend of changing these two parameters, decreasing average annual cloud cover and increasing average daily sunshine generally entails an increase in incident radiation reaching the surface of the South Aegean Region. In the RCP4.5 Scenario and for both periods a reduction of 5 to 10% of the cloud cover will be expected compared to the historical climate and the average daily sunshine duration will increase by 1%. In the RCP8.5 Scenario, a reduction of 5-6% in the period 2021-2050 and 12-16% in the period 2071-2100 is projected, while the average daily sunshine duration increases by 1% in the period 2021-2050 and approximately 2% in the period 2071-2100 compared to the period 1961-1990. In both scenarios the biggest changes are observed in the islands of the Dodecanese.

Estimation of extreme weather events in the South Aegean Region

The impacts of climate change on the natural and man-made environment are not only related to the medium and long-term changes in climatic parameters but also to changes in the frequency and intensity of extreme weather events. For the estimation of these changes in the Region of South Aegean, the average values of the periods 2021-2050 (medium term) and 2071-2100 (long-term) were calculated from the daily values of climatic simulations with Regional Model RACMO2.2 over the period reference 1961-1990 of the following indicators.

Maximum summer and minimum winter temperatures

Based on the results of the RCP4.5 scenario, the minimum winter temperatures in the South Aegean Region are expected to increase by 1.5 ^oC in the period 2021-2050 and by 2.5-3.0 ^oC in the period 2071-2100. Similarly, RCP8.5 scenario is expected to increase minimum winter temperatures by 2^oC in the period 2021-2050 and by 3-4 ^oC in the period 2071-2100.

The following Figures show the changes in the mean maximum summer temperature between the periods 2021-2050 and 2071-2100 and the reference period 1961-1990 for the two scenarios. In the case of the RCP4.5 scenario, the maximum summer temperatures in the South Aegean region are expected to increase by 1.0-1.5 ^oC in the period 2021-2050 and by 2.0-2.5 ^oC in the period 2071-2100, while in the Scripture RCP8.5 in the period 2021-2050 is expected to increase by 1.0-2.0 ^oC and in the period 2071-2100 by 3.0-4.5 ^oC. The rise of this parameter is associated with negative impacts on both anthropogenic environment (e.g. population and infrastructure exposure at significantly higher temperatures) and natural (e.g. increased forest fire risk in combination with other parameters such as precipitation and wind speed).

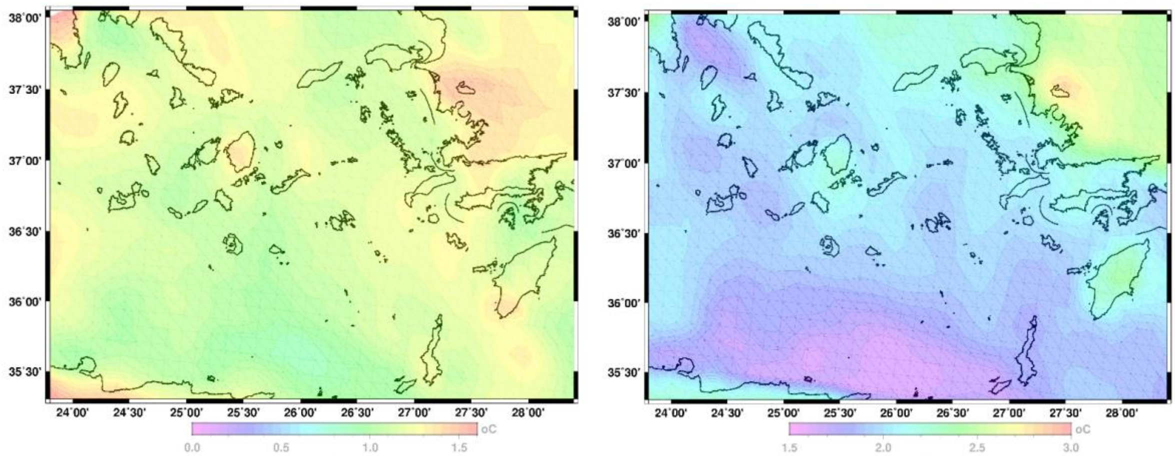

Fig.8: Changes in the mean maximum summer air temperature to 2 m (^oC) between the periods 2021-2050 and 1961-1990 (left), 2071-2100 and 1961-1990 (right) according to the results of climatic simulations with the regional model RACMO2. 2 for the RCP4.5 scenario.

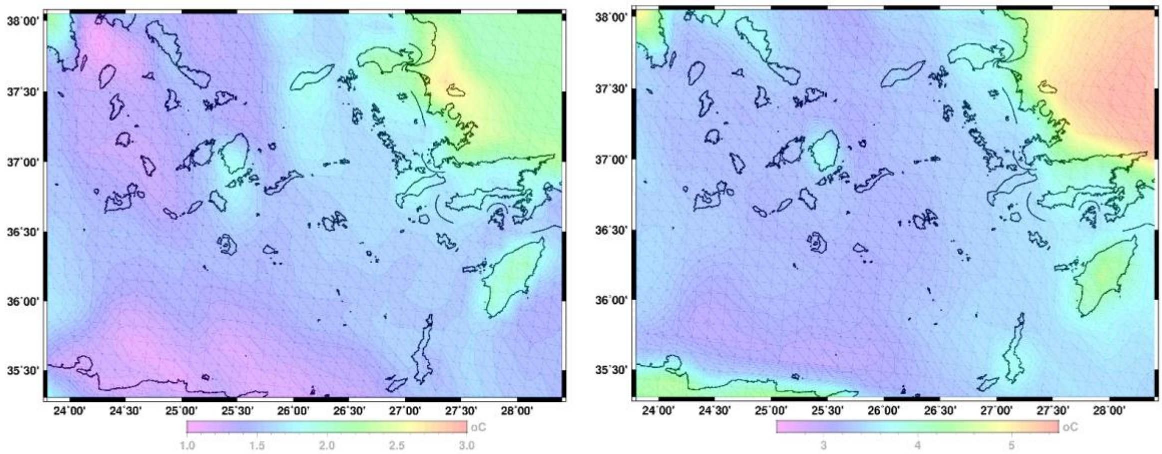

Fig.9: Changes in the mean maximum summer air temperature to 2 m (°C) between the periods 2021-2050 and 1961-1990 (left), 2071-2100 and 1961-1990 (right) according to the results of the climatic simulations with the regional model RACMO2 .2 for the RCP8.5 scenario

Hot Days and Nights - Days of Discomfort

The analysis of climatic models for the estimation of hot days was calculated based on the maximum air temperature at days exceeding 35 °C. In both scenarios, less than two more warm days a year are expected in the two future periods compared to the 1961-1990 reference period due to the positive effect of the sea.

During this study, the changes in the average number of days per year where the minimum air temperature exceeds 20 °C (tropical nights) were examined. In both scenarios, the number of tropical nights is rising across the South Aegean Region. In the mild RCP4.5 scenario 25 to 45 extra nights per year with a minimum temperature of less than 20 °C in the period 2021-2050 compared to the 1961-1990 reference period and from 35 to 70 nights per year in period 2071-2100, are expected. In contrast to the unfavorable scenario RCP8.5, there are between 25 and 55 additional tropical niches per year in the period 2021-2050 and from 60 to 100 in the period 2071-2100. This parameter is quite important as it is directly related to the health of the population as a warm night after a very hot day leads to an increase in the level of discomfort of the population, especially in urban centers.

The impact of climatic conditions on the thermal comfort and discomfort of the population is also assessed with the aid of the HUMIDEX index, which incorporates the influence of moisture [1]. The table below shows the number of days with a HUMIDEX index greater than 38 °C, corresponding to days with a high sensation of discomfort, on the representative islands of the Region for the periods 2021-2050 and 2071-2100 compared to the period 1961-1990.

Table 5: Average number of days with a HUMIDEX index greater than 38 oC for the periods 2021-2050 and 2071-2100 compared to the period 1961-1990 in selected representative islands of the Region for the RCP4.5 and RCP8.5 scenarios

	1961-1990	2021-2050		2071-2100	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
Rhodes	6.0	17.7	25.0	34.1	70.5
Kos	0.0	0.7	2.1	3.4	19.9
Naxos	0.0	0.5	1.0	2.3	10.3
Santorini	0.0	0.0	0.0	0.0	1.1
Karpathos	0.0	0.1	0.5	0.7	9.8
Milos	0.0	0.0	0.0	0.0	2.5
Tinos	0.0	0.0	0.0	0.0	0.1
Patmos	0.0	0.0	0.0	0.0	0.0

According to the results of the climate simulation in the case of the RCP4.5 scenario, expectation is from 6 to 27 extra days per year with a high sense of discomfort in the period 2021-2050 and from 22 and up to 46 additional days in the period 2071-2100. Similarly, in the case of the unfavorable RCP8.5 Scenario, from 10 to 33 additional days per year in the period 2021-2050 and from 55 and up to 86 additional days in the period 2071-2100. The increase in the number of days with a high sense of discomfort is important in the eight islands and much longer than the increase in days with maximum temperatures above 35 ^{o}C, which results in a negative impact on the health of vulnerable groups of the population. The largest increases are observed in the three islands of the Dodecanese, while the smaller increases in the Cycladic islands.

Drought periods

The following Figures show the changes in the maximum duration of dry periods, i.e. consecutive days with total precipitation less than 1 mm per day, between 2021-2050 and 2071-2100 and the historical climate (1961-1990) for the two scenarios examined. Based on the results of both Scenarios between 2021 and 2050, no major changes are expected in the larger part of the Region, with the exception of Kos and the islands of the northern Dodecanese and the islands of the Northern Cyclades, where reductions of 20-30 days are expected. In contrast, during the period 2071-2100, the maximum duration of dry periods of up to 50 days in the Dodecanese (with the exception of Kos) is expected for the RCP4.5 scenario and in the Central and Southern Cyclades and the Northern Dodecanese for the RCP8.5 Scenario.

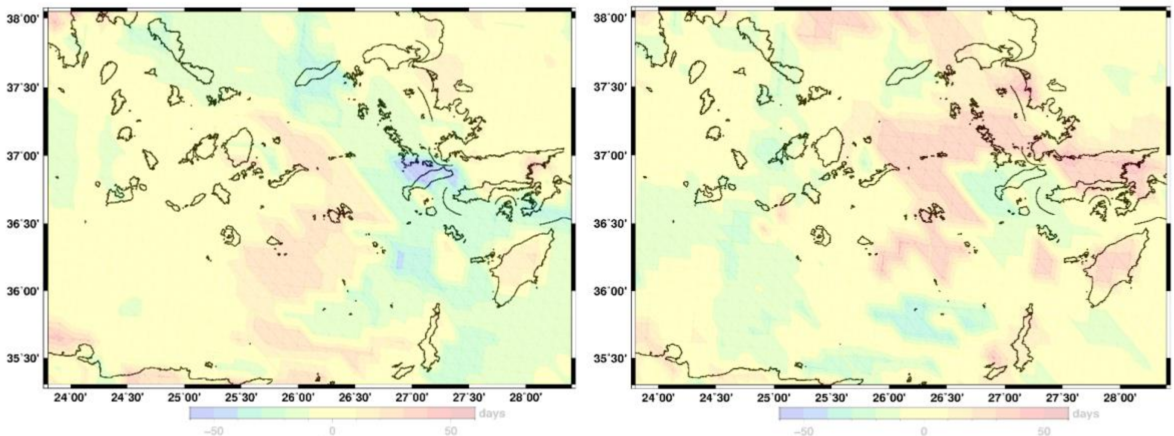

Fig.10: Changes in the maximum dry season duration in days between 2021-2050 and 1961-1990 (left), 2071-2100 and 1961-1990 (right) according to the results of climatic simulations with the regional model RACMO2.2 for the RCP4.5 scenario

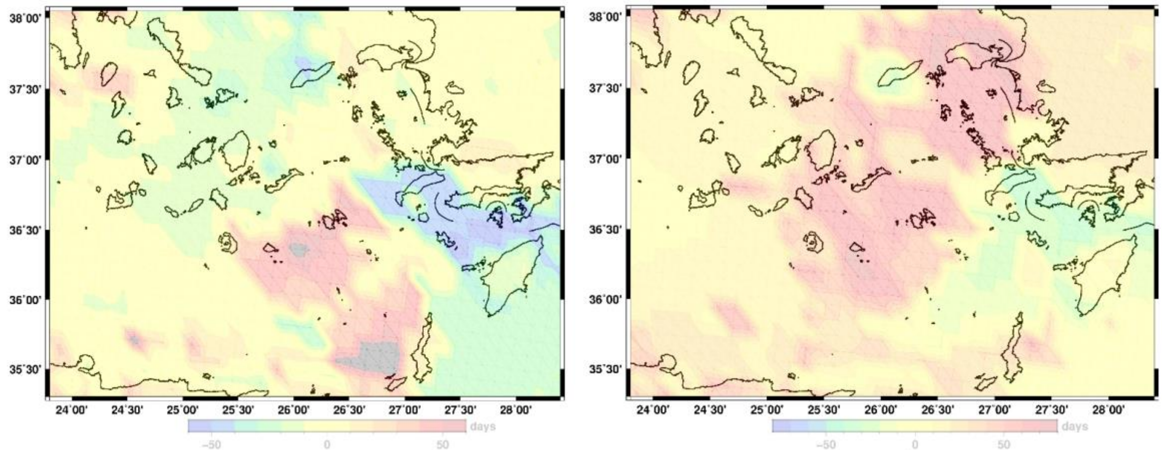

Fig.11: Changes in the maximum dry season duration in days between 2021-2050 and 1961-1990 (left), 2071-2100 and 1961-1990 (right) according to the results of the climatic simulations with the regional model RACMO2.2 for the RCP8.5 scenario

The following Table 6 includes the average number of days per year with daily precipitation less than 1 mm per day (dry days) for the periods 2021-2050 and 2071-2100 compared to the period 1961-1990 in the representative islands of the Region. According to the results of the climatic simulations with the regional model RACMO2.2 in both scenarios there is an increasing trend of this parameter, which is directly related to the expected decrease of the precipitations. In the period 2071-2100 three to nine additional dry days per year are expected according to the RCP4.5 Scenario and from eleven to eighteen extra dry days per year according to the RCP8.5 Scenario.

Table 6: Mean number of days with total precipitation <1 mm for the periods 2021-2050 and 2071-2100 compared to the period 1961-1990 in selected representative islands of the Region for the RCP4.5 and RCP8.5 scenarios.

	1961-1990	**2021-2050**		**2071-2100**	
		RCP4.5	**RCP8.5**	**RCP4.5**	**RCP8.5**
Rhodes	289	295	296	297	307
Kos	291	297	298	297	307
Naxos	292	295	296	297	306
Santorini	297	301	303	302	310
Karpathos	299	304	305	308	317
Milos	295	297	300	300	309
Tinos	296	299	300	300	308
Patmos	294	298	299	299	308

Maximum amount of water precipitated within two consecutive days

For the two scenarios examined, the percentage changes in the maximum amount of water precipitated over a short period (within 48 hours) between the periods 2021-2050 and 2071-2100 and the reference period 1961-1990 are presented in Figures 12 and 13. In the case of the RCP4.5 scenario (Fig. 12), for the period 2021-2050, the value of the parameter is projected to increase from 20% to 30% in most of the Cyclades, the northern Dodecanese and Karpathos and smaller changes in the other islands. In the period 2071-2100, the value of the parameter is expected to increase up to 30% in most of the Cyclades, Kasos and Karpathos and smaller changes to up to 10% in the rest of the Dodecanese islands. In the case of the RCP8.5 Scenario (Fig. 13) for the period 2021-2050, a 20% to 30% increase is projected for the largest part of the Region with the exception of the islands of the northern Cyclades and Rhodes where the changes are small. In contrast, during the period 2071-2100 a decrease of 20% -30% in the islands of the Dodecanese and the Central Cyclades is projected while on the other hand an increase up to 20% in Astypalea and Kasos and in the other islands the changes are small.

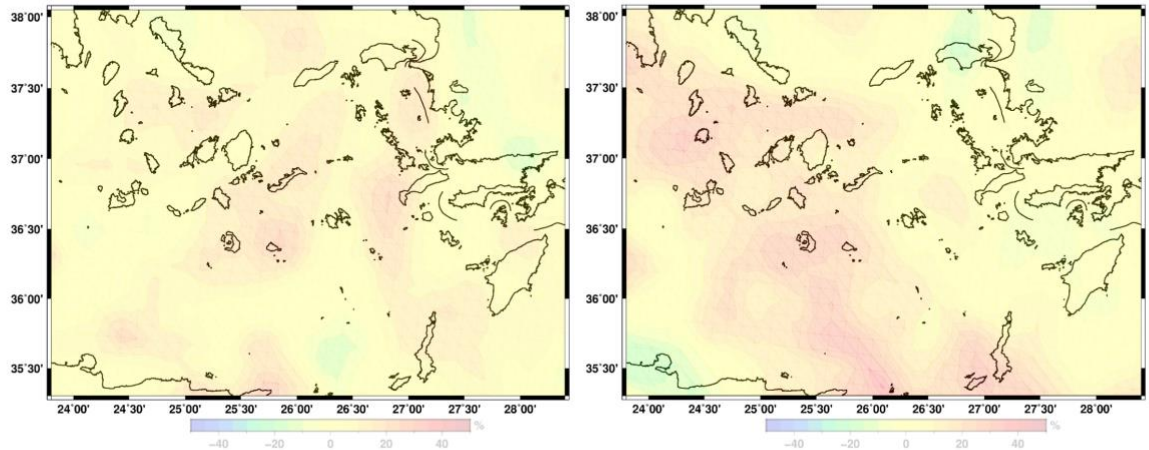

Fig.12: Percentage changes in the maximum amount of water precipitated over two consecutive days between the periods 2021-2050 and 1961-1990 (right), 2071-2100 and 1961-1990 (left) according to the results of climatic simulations with the regional model RACMO2. 2 for the RCP4.5 scenario.

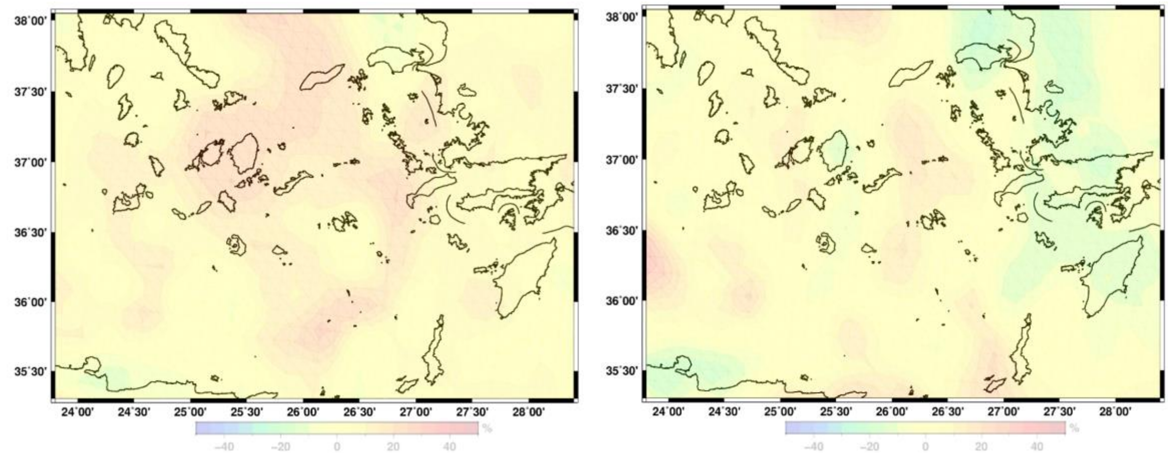

Fig.13: Percentage changes in the maximum amount of water precipitated over two consecutive days between the periods 2021-2050 and 1961-1990 (right), 2071-2100 and 1961-1990 (left) according to the results of climatic simulations with the regional model RACMO2. 2 for the RCP8.5 scenario.

The table below shows the average of the annual maximum hourly precipitation for the periods 2021-2050 and 2071-2100 compared to the period 1961-1990 on the representative islands of the Region. According to the results of the climatic simulations with the regional model RACMO2.2 in both scenarios there is an increasing tendency of this parameter for both periods with the exception of the islands of Rhodes, Kos and Patmos in the period 2071-2100 and in the 2 scenarios. The increase is particularly important in the Cyclades islands and ranges from 10% in the RCP8.5 scenario between 2021-2050 to 30% in the period 2071-2100 in both scenarios.

Table 7: Average annual maximum hourly precipitation in mm for the periods 2021-2050 and 2071-2100 compared to the period 1961-1990 in selected representative islands of the Region for the RCP4.5 and RCP8.5 scenarios

	1961-1990	2021-2050		2071-2100	
		RCP4.5	**RCP8.5**	**RCP4.5**	**RCP8.5**
Rhodes	13.8	15.4	14.3	12.2	11.5
Kos	10.8	13.2	11.9	11.7	10.0
Naxos	7.8	9.6	8.9	10.1	11.3
Santorini	6.5	8.3	7.3	8.2	7.2
Karpathos	7.1	9.2	8.3	10.2	8.1
Milos	6.9	8.1	7.3	9.3	8.6
Tinos	8.0	9.2	8.6	10.0	10.5
Patmos	11.7	11.1	11.6	11.4	11.6

The increasing trend of the maximum quantities of water precipitated over two days and the maximum hourly precipitation in several islands of the Region, combined with the overall reduction in the amount of water precipitated on an annual basis, as well as the increase in the dry periods in the of the Region, it means that more rapid rainfall will occur at short intervals, increasing the risk of floods and landslides, but also negatively affecting the availability of water resources.

Days with strong winds and maximum wind speed

In both Scenarios, no significant changes in the number of days per year are expected with windy winds at speeds of 10m greater than 15 m/s. In the period 2021-2050, based on the results of both Scenarios, up to five extra days per year are expected with winds at speeds of more than 15 m/s in the northern Cyclades, while in the Dodecanese region of two days less a year in Rhodes as two days more in the northern Dodecanese. In the period 2071-2100, up to three days a year are expected with strong winds in the Region for both scenarios under consideration.

Days with high demand for heating and cooling

In the representative islands of the South Aegean Region, the days with high demand for energy for heating and cooling were calculated. The analysis was based on the calibration methodology and the values used in the CCISC report [1], i.e. 15 ^{o}C for the heating days and 26 ^{o}C for the cooling days, were used as the basis temperatures. The results of the analysis for the periods 2021-2050 and 2071-2100 compared to the period 1961-1990 for the two scenarios examined are presented in the following table.

Table 8: Heating and cooling rates on an annual basis for the periods 2021-2050 and 2071-2100 compared to the period 1961-1990 in selected representative islands of the Region for the RCP4.5 and RCP8.5 scenarios. Base temperature for heating days 15 ^{o}C and for cooling days 26 ^{o}C.

Heating Degree Days	**1961-1990**	**2021-2050**		**2071-2100**	
		RCP4.5	**RCP8.5**	**RCP4.5**	**RCP8.5**
Rhodes	496	334	298	221	111
Kos	455	308	270	201	106
Naxos	627	449	399	308	175
Santorini	356	225	193	136	68
Karpathos	275	160	135	91	42
Milos	411	266	227	162	83
Tinos	516	354	308	230	127
Patmos	428	288	251	186	101
Cooling Degree Days	**1961-1990**	**2021-2050**		**2071-2100**	
		RCP4.5	**RCP8.5**	**RCP4.5**	**RCP8.5**
Rhodes	1	9	15	24	96
Kos	0	1	2	4	26
Naxos	0	0	1	2	11
Santorini	0	0	0	0	3
Karpathos	0	0	1	1	13
Milos	0	0	0	0	7
Tinos	0	0	0	0	2
Patmos	0	0	0	0	4

According to the results of the analysis, a reduction of the days with increased heating needs is expected in all the islands of the Region and in both scenarios. In the RCP4.5 scenario, the decrease is 28-42% between 2021-2050 and 51-67% in the period 2071-2100 compared to the reference period 1961-1990. In the RCP8.5 scenario the expected reductions are even higher (36-51% between 2021-2050 and 72-85% in the period 2071-2100).

In terms of high cooling demand days, a significant increase is expected in the summer months in both scenarios. The increase is greatest in the larger islands of the Dodecanese, as in the case of the unfavorable RCP8.5 scenario, it is expected that between 2071-2100 and 96 additional cooling days in Rhodes and up to 26 extra days in Kos. An increase in this parameter combined with the fact that in the summer months the population of the islands is growing significantly due to the tourist season, is expected to lead to an increase in demand for electricity and pressure on the island's electrical systems.

Days with high forest fires risk

The average number of days per year with daily FWI index values greater than 30 (FWI> 30) in the islands of Rhodes, Kos, Karpathos and Naxos for the periods 1961-1990, 2021-2050 was calculated in the South

Aegean RAPCC and 2071-2100. The selection of the islands was based on historical evidence of fires and total losses of agricultural and forest land. Based on the historical data of the period 1983-2008 the islands of the Dodecanese faced greater losses of agricultural and forest land due to fires compared to the islands of the Cyclades. For the calculation of the daily FWI index, the latest Canadian Forest Service algorithm (Wang, Anderson and Suddaby, 2015) and daily data (maximum daily temperature, average daily relative humidity and wind speed and total daily precipitation) were used by the regional model RACMOE2 .2 for Historical Climate and RCP4.5 and RCP8.5 Scenarios. The results of the analysis for the islands of the SAR are shown in the Table below.

Table 9: Number of days with an extremely high forest fire risk (FWI> 30) for the periods 2021-2050 and 2071-2100 compared to the period 1961-1990 in selected representative islands of the Region for the RCP4.5 and RCP8.5 scenarios.

	1961-1990	2021-2050		2071-2100	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
Rhodes	47.6	47.2	47.3	59.4	70.0
Kos	59.6	60.5	63.0	74.2	85.8
Naxos	54.4	54.8	57.5	71.1	81.5
Karpathos	68.8	71.7	74.1	89.6	107.3

According to the results in the period 2021-2050, no significant increase in the days with an extremely increased risk of forest fires is expected. However, the risk increases significantly at the end of the 21st century as between 2071-2100 and 12 to 21 additional days per year in the RCP4.5 Scenario and from 22 to 39 days per year in the RCP8.5 Scenario compared to the historical climate.

Rising sea levels

The average sea level is almost certain (99% -100% probability) that it will continue to increase due to ocean warming and thermal expansion as well as melting glaciers in land and sea areas (glaciers and sea-ice respectively). According to the results of the CMIP5 simulations included in the IPCC 5th Assessment Report on Climate Change and in conjunction with simulation models of the dynamic evolution of the mass of large ice volumes it is estimated that at the end of the century average world sea level will increase in the period 2081-2100 compared to the average price for the period 1986-2005 on average:

- 40 cm in the RCP2.6 scenario,
- 48 cm in the RCP4.5 and RCP6.0 scenarios
- 63 cm in the RCP8.5 scenario

The evolution of the average global sea level rise for the two scenarios examined in the RAPCC of the South Aegean Region (RCP4.5 and RCP8.5) is presented in the following table for the individual years 2020, 2050 and 2080 and the 2021- 2050 and 2081-2100 compared to the year 2000.

Table 10: Estimation of the average (average and breadth) of the average global sea level in cm for the years 2020, 2050, 2080 and the years 2021-2050 from 2000.

Scenario	2020	2021-2050	2050	2080	2081-2100	2100
RCP4.5	7 +/- 2	15 +/- 3	23 +/- 4	40 +/- 8	48 +/-14	54 +/- 17
RCP8.5	7 +/- 2	15 +/- 4	25 +/- 6	50 +/- 13	63 +/- 18	74 +/- 24

For the period 2020-2050, the difference between the two scenarios is negligible and results in a rise of 23-25cm since 2000, with a maximum value of 31cm in the unfavorable RCP8.5 scenario, whereas by the end of the century the differences between two scenarios are significant and end up on an average of 54 cm in the mild RCP4.5 scenario and 74 cm in the unfavorable RCP8.5 scenario with a maximum range of 98 cm in 2100.

Estimation of climate vulnerability

Drawing all the relevant values from the above tables and figures for the South Aegean Region and based on the definition of the reference climate change in Table 2, it is possible to rate the magnitude of change of eight climatic parameters (temperature change, drought, wind, heat waves, rainfall and snowfall, increase of sea level, surges) estimated to be likely to occur in the South Aegean Region by the end of the 21st century for each scenario, time period, and geographic area. The results are presented in the Tables that follow separately for the islands of the Dodecanese and the Cyclades.

Table 11: Rating of climate change estimates in the Cyclades for the two RCP4.5 and RCP8.5 scenarios and the two periods 2020-2050 and 2070-2100. The negative sign (-) shows a decrease

Climatic Parameters	Units	Cyclades Ranking			
		RCP4.5 2021-2050	RCP4.5 2071-2100	RCP8.5 2021-2050	RCP8.5 2071-2100
Temperature Change					
Mean	**Δ°C**	**2**	**3**	**2**	**3**
Maximum	**Δ°C**	**1**	**2**	**1**	**3**
Heating Degree Days net	**Δ Degree Days**	**-1**	**-2**	**-1**	**-2**
Cooling Degree Days net	**Δ Degree Days**	**1**	**1**	**1**	**1**
Forest Weather Index (FWI)	**Δ FWI**	**1**	**2**	**1**	**3**
Drought					
Mean Annual Precipitation	**Δ %**	**0**	**-1**	**-2**	**-4**
Days with precipitation <1mm	**Δ days**	**-1/1**	**-2/+2**	**-2/+2**	**4**
Wind					
Mean Speed	**Δ m/s**	**0**	**0**	**0**	**0**
Days with wind speed >15m/s	**Δ days**	**1**	**-1**	**1**	**-1**
Heat waves					
Days with maximum T >35°C	**Δ days**	**1**	**1**	**1**	**1**
Days with Humidex > 38	**Δ days**	**0**	**0**	**0**	**0**
Cold invasions and Frost					
Days with minimumT < 0 °C	**Δ**	**0**	**0**	**0**	**0**
Rainfall and Snowfall					
Two days height of precipitation	**Δ%**	**1/2**	**1/3**	**1/2**	**-2/2**
Decrease of snowfall height	**Δ%**	**-3**	**-3**	**-2**	**-4**
Increase of sea level					
Sea Level	**Δcm**	**0**	**2**	**0**	**3**
Surges					
Increase of maximum height	**Δ %**	**1**	**1**	**1**	**1**

Rank	Risk
0	**Negligible**
1	**Small**
2	**Medium**
3	**High**
4	**Extreme**

Table 12: Rating of climate change estimates in the Dodecanese for the two RCP4.5 and RCP8.5 scenarios and the two periods 2020-2050 and 2070-2100. The negative sign (-) shows a decrease

Climatic Parameters	Units	Dodecanese Ranking			
		RCP4.5 2021-2050	RCP4.5 2071-2100	RCP8.5 2021-2050	RCP8.5 2071-2100
Temperature Change					
Mean	Δ°C	2	3	2	3
Maximum	Δ°C	1	2	1	3
Heating Degree Days net	Δ Degree Days	-1	-2	-1	-2
Cooling Degree Days net	Δ Degree Days	1	1	1	1
Forest Weather Index (FWI)	Δ FWI	1	2	1	3
Drought					
Mean Annual Precipitation	Δ %	-1	-2	-2	-4
Days with precipitation <1mm	Δ days	-1/1	-2/+2	-2/+1	-2
Wind					
Mean Speed	Δ m/s	0	0	0	0
Days with wind speed >15m/s	Δ days	1	-1	1	-1
Heat waves					
Days with maximum T >35°C	Δ days	1	1	1	1
Days with Humidex > 38	Δ days	0/2	0/3	0/2	2/4
Cold invasions and Frost					
Days with minimumT < 0 °C	Δ days	0	0	0	0
Rainfall and Snowfall					
Two days height of precipitation	Δ%	1/2	1/2	1/2	-2/1
Decrease of snowfall height	Δ%	0	-3	0	-3
Increase of sea level					
Sea Level	Δcm	0	2	0	3
Surges					
Increase of maximum height	Δ %	1	1	1	1

Rank	Risk
0	Negligible
1	Small
2	Medium
3	High
4	Extreme

Climate risk assessment results

To compare the impacts of climate change on the sectors and activities examined, the climate change risk is assessed through the following common 5-scale classification (negligible, small, medium, high, extreme 0 to 4).

Each activity and sector were ranked in terms of the risk of each climatic parameter (expressed by the most activity-related element if there are more than one) essentially as the percentage of the calculated values of each parameter relative to the reference value under which the vulnerability has been estimated. The analysis is performed for all sectors and activities separately for each scenario, time period and geographical area.

The climatic risk of each activity and sector by climatic parameter was calculated as the product of climate change risk and sector / activity vulnerability for each parameter according to step VIII of the methodology.

The degree of each hazard is then normalized on a scale from 0 to 1 to allow for an overall activity estimate of all the impacts of the change of the eight main climatic parameters. Here it should be noted that some of the effects may be positive, such as the increase in wind speed compared to wind energy and the increase in temperature in relation to the efficiency of photovoltaics but also the reduction of rainfall in relation to flood and landslide damage. This favorable effect is counted in the sum of the impacts by reducing the overall level of risk. The overall climatic risk of each activity / sector was ultimately calculated by the sum of the individual risks from each climatic parameter if it has an effect and was re-classified on a 5-point scale (negligible, small, medium, high, extreme). By combining all the risk assessments for the two scenarios, the two periods and the two geographical areas, it was possible to estimate the overall risk of each activity in order to classify the priorities both at sectoral level and geographical area and proceed with the design of the adaptation actions.

According to this procedure the overall risk estimation for the climate change impact per sector was presented in the following Figures 14 and 15 for Cyclades and Dodecanese respectively.

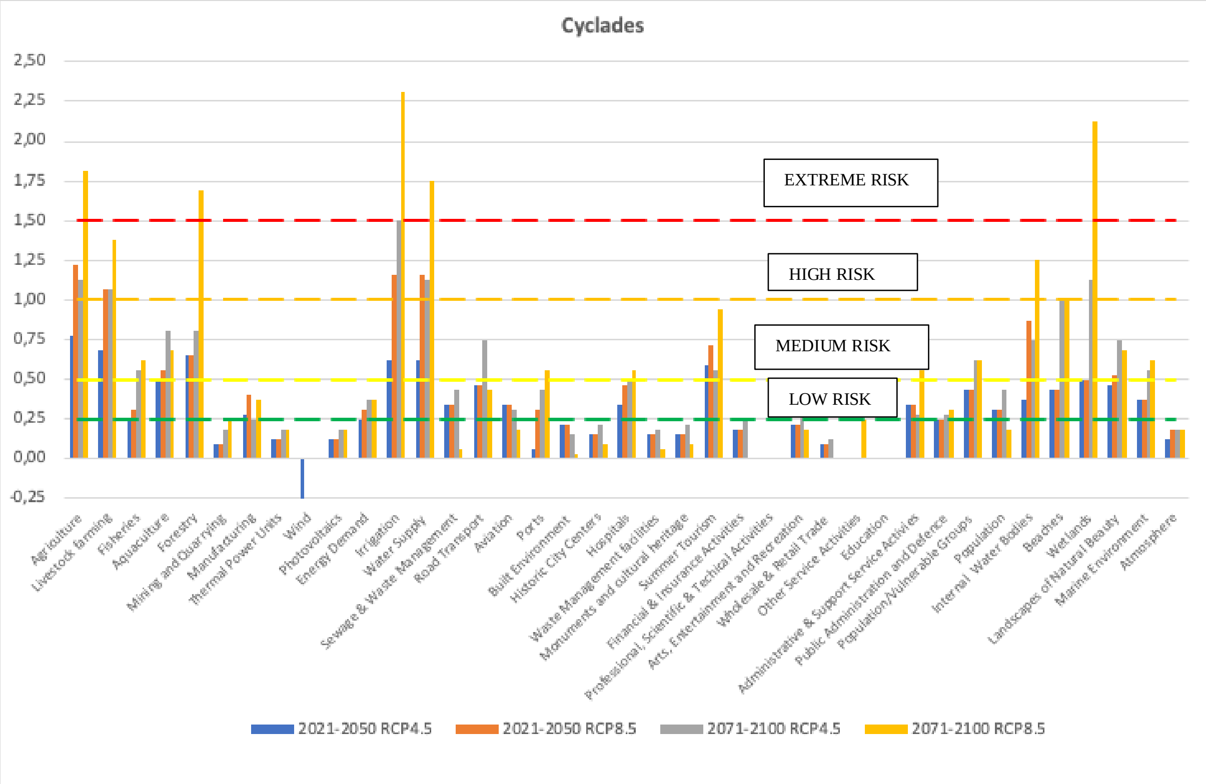

Fig.14: Total Climate Risk Assessment per activity in the Cyclades for the periods 2021-2050 and 2071-2100 and the RCP4.5 and RCP8.5 scenarios

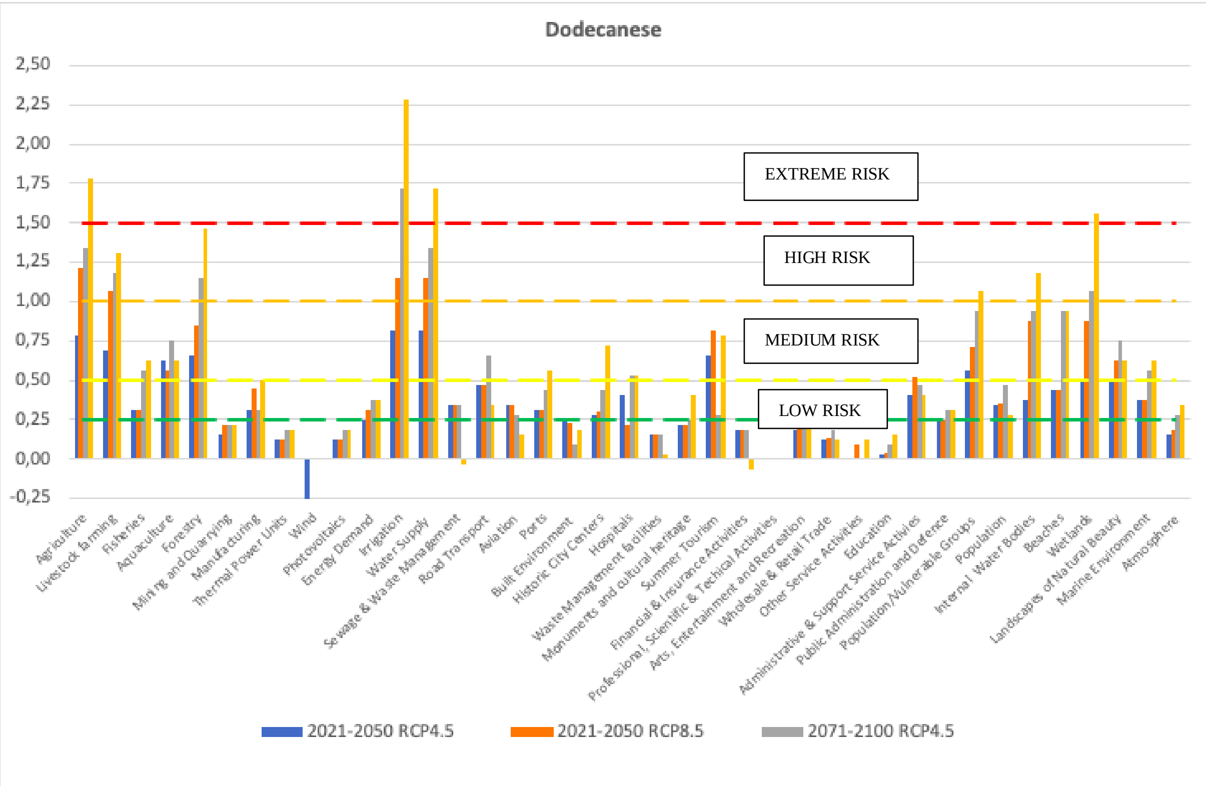

Fig. 15: Total Climate Risk Assessment per activity in the Dodecanese for periods 2021-2050 and 2071-2100 and the RCP4.5 and RCP8 scenarios

Based on the results of the analysis in the short and medium term up to 2050 it is estimated that the following sectors are categorized as high risk due to the effects of climate change (depending on the evolution scenario of GHG concentrations in the atmosphere):

- the activities of the primary sector (agriculture, livestock farming and aquaculture);
- water resources (irrigation & water supply)

Moderate risk in the short and medium term is also expected to address:

- Tourism sector,
- Public Health (mainly in the islands of the Dodecanese)
- Forest systems,
- Biodiversity, inland waters and protected areas (wetlands, biotopes).

In the long term period (2071-2100), climatic risk increases significantly for most areas in SAR and especially in the case of the unfavorable scenario, RCP8.5 receives extreme values for the following areas:

- Water resources,
- Forest systems,
- Agriculture and
- Protected areas.

Medium and high risk over the long term is expected to address the following areas:

- Livestock farming,
- Fishing and aquaculture,
- Coastal areas,
- Port infrastructure,
- Road transport,
- Public Health and Health Infrastructure,
- Tourism sector,
- Landscapes of special beauty and
- Aquatic environment

The remaining sectors (manufacturing, mining, air transport, building infrastructure, tertiary sector, etc.) in both the short and the long term are estimated to be at low risk.

Action Plan – Proposed Adaptation Measures

The proposed Action Plan is organized on priority axes and sub-categories of key actions including indicative measures and interventions aiming at adapting the Region to Climate Change within the framework of the National Strategy. A key element for the evaluation and prioritization of the proposed measures is their effectiveness with respect to the objectives set by national and EU legislation.

In line with the guidelines given to the National Climate Change Adaptation Strategy to constitute the measures, part of the decentralized, effective and efficient policies should deliver the desired results at the lowest possible cost, the highest possible consensus and the highest possible correlation with the other objectives of regional policy. The documentation of the feasibility of implementation is directly related to the weighting of the consequences of the implementation. For this purpose, measurable performance indicators of the proposed measures that are directly related and viable should be defined.

The quantification of the effectiveness of the measures is done by setting measurable performance indicators for each of them. The performance indicator refers to the degree of correlation with the objectives set out in National Legislation 11258/2017. In particular, the index takes the following values (1 to 3), respectively, with its correlation to the above objectives.

Table 13: Values of indicator's performance

Objective	Values of Performance indicator
(A): avoid the impact	3
(B): reduce intensity and extent of impacts	2
(C): rehabilitation of the impacts of climate change	1

Therefore, a measure that helps to avoid the impact (Objective A - Performance Indicator Value= 3) is considered to be most efficient, as opposed to a measure that only contributes to rehabilitation (Objective C - Performance Indicator Value= 1), based on the above classification.

The Cost / Effectiveness Ratio is an indicator that makes a first assessment and hierarchy of measures. This indicator is derived by dividing the estimated budget of each measure by the performance index value as described above and is attributed for convenience to a scale of 0-100.
For the evaluation, the measure with the lowest ratio is considered as the most effective measure, as it is a measure that produces the maximum yield (Performance Score: 3) at the lowest possible cost (low budget).

In the second step, the economic, environmental and social benefits resulting from the implementation of the proposed measures and actions were assessed and taken into account in the prioritization of the measures in order to take precedence a) environmentally, economically and socially useful, and (b) measures that are effective for a wide range of climate change.

To assess the benefits of implementation, a number of factors were being explored, by category of benefits.

Table 14: Investigating factors by category of benefits

Benefits category	Factors
Environmental Benefits	Degree, time and duration of improvement
Financial Benefits	Saving resources
Social Benefits	Beneficial population

According to these categories the beneficial indicator was introduced. Measures that provide benefit in one of the above three benefit categories take value equal to 1, and if they have benefits in two or three categories, they get a value of 2 or 3 respectively.

Hierarchy and evaluation of proposed measures

At the first level of ranking, according to the analysis presented previously, the table below shows the classification of the proposed measures based on effectiveness and benefits. In order to classify the measures, a cumulative score is obtained for each of them, resulting from the following formula:

$$\text{Total Score} = \frac{\textit{Performance Indicator} + \textit{Beneficial Indicator}}{\textit{Cost / Effectiveness}}$$

According to this rating, measures with maximum efficiency and most and most important benefits, while at the same time low cost / effectiveness, receive higher ratings and are ranked higher.

In the next stage, the proposed measures are evaluated and classified in order to prioritize sectors and activities based on global climate risk. Measures in the high-risk climatic sectors appear higher in the ranking of the table below.

For the final evaluation and prioritization of the proposed measures, all of the above are taken into account and their ranking is classified in High, Medium and Low Priority. Higher rankings therefore show those measures that have received a high aggregate score and at the same time belong to high risk climatic sectors.

Table 15: Overall hierarchy of proposed measures

Measure Code	Measure- Action	Total Score	Prioritization
NA_D1	Regional Climate Change Adaptation Observatory	1410,00	H
NA_D2	Adaptation measures in municipalities level	65,45	M
NA_D3	Civil Protection Adaptation Actions	214,00	H
NA_D4	Vulnerability assessment by individual activity of the primary sector	2800,00	H
NA_D5	Adaptation of agricultural activities	384,00	H
NA_D6	Adaptation of livestock activities	12,80	M
NA_D7	Adjustment of Fisheries and Aquaculture	4,80	M
NA_D8	Protection of Forest Ecosystems	66,67	H
NA_D9	Protection and Adaptation of Extractive Industries	0,80	L
NA_D10	Completing energy interconnection infrastructure with the continental network	4,86	M
NA_D11	Adaptation of autonomous thermoelectric units to non-interconnected islands	4,80	M
NA_D12	Protect and customize interconnectors for interconnected islands	54,00	M
NA_D13	Promoting energy efficiency and the use of renewable energy sources	437,00	H
NA_D14	Recording, assessment of water resources, projects and infrastructures at NUTS3 level	162,00	H

Measure Code	Measure- Action	Total Score	Prioritization
NA_D15	Action plan for the protection of underground aquifers	224,00	H
NA_D16	Action plan optimal management of surface water resources	140,00	H
NA_D17	Action plan for optimal water and irrigation systems management	56,00	M
NA_D18	Addressing the Southern Aegean Water Scarcity and Drought	22,50	M
NA_D19	Monitoring of the Quality and Quantitative Status of Water Resources of the Southern Aegean Region	70,00	H
NA_D20	Action plan for optimal management of source discharges	30,00	M
NA_D21	Adaptation and protection of infrastructure and means of road transport	93,33	H
NA_D22	Adaptation and protection of port infrastructure	3,60	L
NA_D23	Adaptation and protection of airport infrastructures	3,00	L
NA_D24	Institutional interventions for adaptation	84,00	H
NA_D25	Design of building stock protection and protection	9,00	M
NA_D26	Urban regeneration of cities through regeneration of areas and buildings belonging to municipalities to create and maintain a microclimate	48,00	M
NA_D27	Protection from Flooding in Urban and Peripheral Areas	89,72	H
NA_D28	Adjustment of heating-cooling systems in buildings	16,00	M
NA_D29	Adaptation of tourism businesses and infrastructure	997,56	H
NA_D30	Adaptation of tourism services (diversification of tourism products)	880,00	H
NA_D31	Vulnerability assessment of the most vulnerable coastal areas and adaptation measures	208,00	H
NA_D32	Design Study and Construction of Coastal Construction Projects	4,67	L
NA_D33	Integrated Coastal Zone Management Program	60,00	M
NA_D34	Actions to protect / conserve, promote, monitor and restore biodiversity and local sensitive ecosystems and areas NATURA	38,10	M
NA_D35	Actions for the protection of freshwater aquatic ecosystems	40,00	M
NA_D36	Actions to protect biodiversity of the marine environment from alien species	120,00	H
NA_D37	Establishment of Specific Action Plans to Address Health Problems Due to Climate Change and Extreme Effects	150,00	H
NA_D38	Health disaster management training for social organization and emergency / emergency management due to sudden disasters	630,00	H

Also, the RAPCC for the South Aegean Region described the necessity for organizing a solid monitoring methodology. This could be implemented by the Regional Climate Change Observatory by designing specialized climate change adaptation indicators separated in process-based, output-based, outcome-based combining quantitative and qualitative information and providing a strong base for assessing adaptation progress and performance [3].

CONCLUSION

The South Aegean Region is an island region separated in two island groups Cyclades and Dodecanese. The analysis of the climatic vulnerability and danger and hence risk of the different sectors and activities of the South Aegean Region was carried out for the short and medium term (2021-2050) and long-term horizons (2071-2100) and distinct for the geographical units of Cyclades and Dodecanese. Several climatic parameters like temperature, precipitation, humidity, wind speed and cloud cover and sunshine duration were taken into account. Moreover, for the estimation of the climatic vulnerability additional extreme climatic events were analyzed like Maximum summer and minimum winter temperatures, Hot Days and Nights - Days of Discomfort, Drought periods, Maximum amount of water precipitated within two consecutive days, Days with strong winds and maximum wind speed, Days with high demand for heating and cooling, Days with high forest fires risk.

The analysis of climatic vulnerability showed that in the case of RCP8.5 scenario more extreme climatic changes will occur. Specifically, extreme drought events will be more severe due to great decrease in mean annual precipitation for both Dodecanese and Cyclades. In Cyclades more days with precipitation lower than 1mm are predicted for RCP8.5 scenario than in Dodecanese. Also, the magnitude of decrease in snowfall will be more intense in Cyclades. In general, higher mean temperatures, increase of drought events, increase of sea level and higher Forest Weather Index will be the more significant climatic hazards.

Based on the results of the analysis in the short and medium term up to 2050, the following activities are exposed to medium to high risk from the effects of climate change (depending on the evolution scenario of GHG concentrations in the atmosphere):

- the activities of the primary sector (agriculture, livestock farming and aquaculture);
- water resources (irrigation & water supply).

In the long run (2071-2100), climatic risk increases significantly for most areas in SAR and especially in the case of the unfavorable scenario, RCP8.5 reaches extreme values for the following sectors:

- Water resources,
- forest systems,
- agriculture and
- Protected areas.

In order to design and classify the sectoral adaptation actions, an extensive consultation process with the regional authorities was developed while specific data scarcity was revealed. According to these findings the proposed measures in the RAPCC were based on island specific characteristics such as financial-social activities, geomorphology and developed both in horizontal and sectoral actions and were adjusted in each of the two main island groups.

References:

[1] CCISC, 2011. The Environmental Economic and Social Impacts of Climate Change in Greece. Climate Change Impacts Study Committee (CCISC). Bank of Greece, Athens pp. 64-96.

[2] Climate Adapt. Sharing Adaptation Information Across Europe. www.climate-adapt.eea.europa.eu

[3] EEA, 2017. Climate change, impacts and vulnerability in Europe 2016 An indicator-based report. EEA Report No 1/2017. European Environment Agency

[4] ELSTAT, 2017. GDP and Employment Indices in the years 2005 to 2015, Hellenic Statistic Authority

[5] Eurostat, 2017: Map 2: Number of nights spent at tourist accommodation establishments relative to population sixe, by NUTS 2 regions 2015. Eurostat Regional Yearbook 2017.

[6] IPCC, 2007. Climate change: impacts, adaptation & vulnerability. In: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press.

[7] Jacob, D., Petersen, J., Eggert, B. et al., 2014: EURO-CORDEX: new high-resolution climate change projections for European impact research, Reg Environ Change 14: 563, https://doi.org/10.1007/s10113-013-0499-2

[8] Joint Ministerial Decision on the revision of the national list of Natura 2000 European ecological sites with no. 50743 / 15.12.2017 (Government Gazette 4432B)

[9] M.D. (Ministerial Decision) 11258/2017 “Content Specialization of Regional Climate Change Adaptation Plans, in accordance with article 43 of Law 4414/2016”. Ministry of Environment and Energy. http://www.ypeka.gr/LinkClick.aspx?fileticket=uoS9qGeUPaE%3D&tabid=303&language=el-GR

[10] National Climate Change Adaptation Strategy, 2016. Ministry of Environment and Energy. https://www.bankofgreece.gr/BogDocumentEn/National_Adaptation_Strategy_Excerpts.pdf

[11] UBA, 2017. Guidelines for Climate Impact and Vulnerability Assessments. Recommendations of the Inerministerial Working Group on Adaptation to Climate Change of the German Federal Government. German Environment Agency (Umweltbundesamt – UBA)

[12] Van Wagner, C.E., 1987: Development and structure of the Canadian Forest Fire Weather Index System. Can. For. Serv., Ottawa, ON. For. Tech. Rep. 35. Also available at http://cfs.nrcan.gc.ca/ publications/download-pdf/19927.