AdriaClim

Climate change information, monitoring and management tools for adaptation strategies in Adriatic coastal areas

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D5.6.1 Climate adaptation plan of coastal areas of the Apulia Region within the Programme area

PP08 – Regione Puglia

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Areas of Interest in the Plan: Aquaculture, Coastal erosion, Tourism.

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Index

1. Introduction......3
1.1 Bibliography......6
2. Current and future climate analysis of the Apulia region......8
2.1 Introduction......8
2.2 Methodological process......8
2.3 Current and future climate analysis of terrestrial areas......9
2.4 Current and future climate analysis of sea areas......45
2.5 Bibliography......48
3. Analysis of climate change impacts in Apulia, sectoral vulnerabilities and adaptation actions......51
3.1 Impacts and adaptation actions for aquaculture......51
3.1.1 Analysis of the current scenario for the sector......51
3.1.1.A. Analysis of the aquaculture sector in Apulia......55
3.1.2 Analysis of expected impacts......58
3.1.3 Adaptation actions......66
3.1.4 Bibliography......75
3.2 Impacts and adaptation actions for coastal erosion......82
3.2.1 Analysis of the current scenario for the industry......83
3.2.2 Analysis of expected impacts......99
3.2.3 Adaptation actions......103
3.2.4 Bibliography......107
3.3 Impacts and adaptation actions for tourism......110
3.3.1 Analysis of the current scenario for the industry......111
3.3.2 Analysis of expected impacts......117
3.3.3 Adaptation actions......128
3.3.4 Bibliography......138
4. Participation, monitoring, and governance......148
4.1 Bibliography......152

1. Introduction

Climate change is one of the most significant challenges to be faced globally and also for Italy. Indeed, Italy is located in the so-called "Mediterranean hot spot," an area identified as being particularly vulnerable to climate change (EEA, 2012; IPCC AR.5, 2014; IPCC AR.6, 2023).

In the European framework, for the first time climate adaptation finds a more in-depth focus in the 2013 EU Strategy on Adaptation to Climate Change, whose main aim is to make Europe more resilient by pursuing the goal of increasing the adaptive capacity of individual states and minimising the adverse effects of climate change (EC, 2013). The Strategy contains principles and guidelines for individual states to adjust their adaptation policies, using tools and resources that the European institutions themselves have made available to implement the Strategy. As an example, we would like to mention the Climate-ADAPT platform (Climate-ADAPT, 2012), set up in 2012 by the collaboration between the European Commission and the European Environment Agency (EEA).

The Covenant of Mayors for Climate and Energy (EC, 2016), an initiative launched in 2015 in the wake of the 2013 EU Strategy, envisages the voluntary adherence of regional and local entities that are committed to the implementation of Sustainable Energy and Climate Action Plans, i.e. planning tools through which various objectives are pursued, including the integration of adaptation and mitigation of climate change.

In 2021, the European Commission updated the 2013 Strategy by introducing the new EU Strategy on Adaptation to Climate Change *(Forging a climate-resilient Europe*) (EC, 2021). The new strategy, whose vision includes a more resilient Europe and the achievement of climate neutrality, recognises Member States as the key actors to implement adaptation proposals. It also promotes a smarter, systemic and rapid adaptation marked by the development of local and international actions. A smart adaptation involves increased quantity and quality of data regarding climate-related risks with a focus on the consequences and costs of non-action. With a view to a more systemic adaptation, the drafting of adaptation strategies and plans by the different stakeholders and the integration of these tools with monitoring and evaluation plans becomes crucial. Although the adaptation response needs to be implemented at all levels of governance, adaptation at the local level is very important, and the EU aims to strengthen this, also with the support of the work carriedout under the Covenant of Mayors.

With reference to the Italian situation, the Ministry for Environment, Land and Sea Protection (MATTM) adopted, by MATTM/CLE Directorial Decree of 16 June 2015, no. 86, the National Strategy on Adaptation to Climate Change (SNACC, 2015). At national level, the Strategy is the first document setting out the vision and general objectives to be achieved in order to start implementing an adaptation pathway in Italy.

The SNACC reports the state of knowledge on the impacts and vulnerabilities of individual sectors (environmental, social and economic) through key concepts. It also offers a set of proposed adaptation actions for each type of sector, including identifying criteria by which to evaluate priority actions.

The operational tool for implementing the National Strategy is the National Climate Change Adaptation Plan (NCCAP, 2022). The NCCAP is designed to support regional and local authorities in managing climate change impacts as it contains a common base of data, information and analysis methodologies useful for identifying sectoral impacts and related adaptation actions. Adapting to climatic impacts requires complex planning and an appropriate governance system to guide the various stakeholders in defining specific objectives and implementing adaptation actions.

In line with what has been proposed at international and national level, the Apulia Region has initiated a pathway of policies related to the effects of climate change on various environmental aspects.

The first step taken by the Region was the establishment of an inter-departmental working group on climate change with advisory functions, coordinated by the then Department of Environmental Quality through Resolution of Regional Council No. 2180 of December 28, 2016.

Through Act no. 1154 of 30/07/2017, subsequently amended by Resolution of Regional Council no. 1965/2019, the Apulia Region was nominated to the European Commission as Coordinator of the 'Covenant of Mayors for Climate and Energy'. A Regional Coordination Structure was established to support Local Authorities in planning actions to address, in a coordinated way and with a joint strategy, the potential impacts of climate change through mitigation and adaptation policies.

In April 2018, the President of the Apulia Region signed the Declaration of Commitment of the Territorial Coordinators in order to support the Covenant of Mayors' vision for de-carbonised territories capable of adapting to climate change, in which access to secure, sustainable and affordable energy must be ensured.

In 2019, the process of defining the Regional Strategy of Sustainable Development (SRSvS) was initiated. This led to a deepening of connections and synergies between sustainable development goals and national and regional actions for climate change adaptation.

Consistent with the actions proposed at the European and national levels, by Resolution of Regional Council no. 1575 of Sept. 17, 2020, the process of defining the Regional Strategy on Adaptation to Climate Change (SRACC) was initiated, in order to systemise currently available experience and information in order to identify appropriate measures to strengthen territories' resilience.

The objective of the Regional Strategy on Adaptation to Climate Change is to provide detailed information to Local Authorities in order to support the drafting of Sustainable Energy and Climate Action Plans (SEAPs), enabling the achievement of the 2030 Agenda objectives in the Apulian territorial context.

In the European and international arena, there are various project experiences on the topic of adaptation.

In 2019, within the framework of the LIFE project 'Master Adapt' (2019), a guidance document aimed at regional administrations was drafted to promote the integration of the climate change adaptation process into planning instruments. These guidelines illustrate the underlying guiding principles of drafting a regional adaptation strategy, the key steps for its development (climate analysis, impact analysis, stakeholder consultation, governance, monitoring), adaptation solutions aimed at increasing the adaptive capacity of a territory and identifying the opportunities generated.

Among the projects implemented through the Interreg V-A Italy-Croatia Cooperation Programme 2014/2020 is the 'AdriAdapt' Project (https://adriadapt.eu/) (2019-2021), which is a knowledge platform on resilience for Adriatic cities. Consulting this platform promotes the comparison of adaptation measures affecting different territories on the Adriatic coast.

Within the RESPONSe Project - "Strategies to adapt to climate change in Adriatic regions" (https://programming14-20.italy-croatia.eu/web/response), financed with resources from the Interreg V-A Italy - Croatia Cooperation Programme 2014/2020 and approved through the Resolution of Regional Council of 18 June, 2019, no. 1076, Apulia produced, as a project partner, the Sustainable Energy and Climate Action Plan for the pilot area of the city of Brindisi. The objective of the project was, in fact, to support Adriatic coastal municipalities in adopting smart governance in response to the risks and impacts resulting from climate change, and in defining an action plan based on the characteristics of the territory.

This document was drafted under the Project "AdriaClim - Climate change information, monitoring and management tools for adaptation strategies in Adriatic coastal areas"(https://programming14-20.italy-croatia.eu/web/adriaclim) approved by Resolution of Regional Council no. 1546 of September 17, 2020, funded with resources from the Interreg V-A Italy-Croatia Cooperation Program 2014/2020. The project, co-ordinated by ARPA Emilia-Romagna, aims to consolidate climate change monitoring, to plan measures for the strengthening of adaptation capacity in Italy and Croatia through cross-border co-operation, to improve climate monitoring systems and to process innovative data to promote knowledge and co-operation for the planning of adaptation strategies in the marine and coastal environment.

The objective of this document is to provide guidelines for adaptation to climate change, with regard to the aquaculture sector, the phenomenon of coastal erosion and the tourism sector. An assessment of the expected climate anomalies in the Adriatic regional context is followed by an analysis of the possible impacts of climate change in the three reference areas. On the basis of the identified impacts, adaptation actions tailored to territorial needs are proposed.

Finally, it should be remembered that adaptation to climate change is almost always connected to the issue of climate mitigation. The latter presupposes the need to apply carbon emission reduction policies that act according to a top-down approach on a large scale, usually national or supranational (in line with EU Regulation 1119/2021).

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2. Current and future climate analysis of the Apulia region

2.1 Introduction

Climate change, as reported in the extensive literature of the Intergovernmental Panel on Climate Change (IPCC), leads to complex variations in climate characteristics, acting on different spatial and temporal scales. Climate change can influence the frequency, intensity, spatial extent and duration of extreme weather events, as well as phenomena such as sea level rise, which affect larger spatial-temporal scales (Seneviratne et al., 2012; Lee et al., 2021).

The impacts of climate change, defined as "the effects on natural and human systems of extreme weather and climate events and of climate change" (IPCC, 2014a), result in increased risks to humans and all other life on Earth (Lee et al., 2021).

The study and definition of climate and the understanding of the phenomena that regulate its possible future evolution become fundamental for the correct and adequate definition of climate change adaptation strategies (Seneviratne et al., 2012). This requires the development of a medium- to long-term strategic vision that considers both the possible risks and opportunities associated with climate change.

In fact, in order to be effective, adaptation measures will have to be based on scientific evidence to act in the most appropriate and timely manner on the effects of climate change with the aim of reducing the vulnerability of environmental systems and socio-economic sectors and limiting any associated damage (Giordano et al., 2018).

2.2 Methodological process

The methodological process adopted refers to that described in the National Climate Change Adaptation Plan (PNACC, 2022). Terrestrial and sea areas are analysed separately, considering two different time horizons: the current period and the future period.

For the study of the future period, three different IPCC (Intergovernmental Panel on Climate Change) emission scenarios are referred to in the PNACC: RCP8.5 'No mitigation', RCP4.5 'Strong mitigation' and RCP 2.6 'Aggressive mitigation'.

RCP (Representative Concentration Pathways) scenarios are climate scenarios expressed in terms of greenhouse gas concentrations in the atmosphere. They are used to conduct climate simulations to highlight possible future climate developments.

The future scenarios considered in this analysis are RCP8.5 and RCP4.5, described below:

- **RCP8.5** - considers the growth of emissions at current rates. This scenario assumes that, by 2100, atmospheric CO_2 concentrations will triple or quadruple (840-1120 ppm) from pre-industrial levels (280 ppm) (IPCC, 2014b);
- **RCP4.5** - assumes the implementation of some initiatives to control emissions. It is regarded as a stabilisation scenario: by 2070, CO_2 emissions fall below current levels and atmospheric concentrations stabilise at about twice pre-industrial levels by the end of the century (IPCC, 2014b).

Climate analysis makes use of specific climate indicators, derived from one or more fundamental meteorological quantities. The use of indicators makes it possible to show the average climatic trend in a given geographical area and to identify possible changes in the future climate, compared to the current period under consideration. These are referred to as climate anomalies.

2.3 Current and future climate analysis of terrestrial areas

This section reports the results of the climate analysis for the terrestrial areas of the Apulia region. An initial part dedicated to the analysis of the current climate condition is followed by an assessment of the expected climate anomalies for the future period, according to the RCP8.5 and RCP4.5 emission scenarios.

The set of climate indicators, on which the climate analysis of terrestrial areas was conducted, is shown in Table 2.1, where the following information is given for each indicator:

- the atmospheric variable on which it is based;
- the description of the climate indicator;
- the time scale on which the indicator is evaluated (seasonal/annual);
- the unit of measurement of the indicator.

The rainfall and temperature data, used to calculate climate indicators, were obtained from the gridded dataset "*Dynamical Downscaling with COSMO-CLM of historical (1979/2005) and future climate (2006/2100) data under scenario RCP4.5 and RCP8.5 at 8km over Italy*" prepared by the Euro-Mediterranean Centre on Climate Change (CMCC).

This dataset provides daily precipitation and temperature data on a regular grid with 8x8km resolution over the entire national territory (Bucchignani et al., 2016; Zollo et al., 2016), generated with the regional climate model COSMO-CLM (Rockel et al., 2008), which in turn is driven by the global climate model CMCC-CM (Scoccimarro et al., 2011).

The data available in the dataset covers the "historical" time frame from 1979-2005, taken as the reference period, and "future" from 2006-2100 for the IPCC RCP8.5 and RCP4.5 scenarios. In the present study, future climate analysis was conducted for the period 2021-2050.

Indicators		Atmospheric variable	Description	Time scale	Unit of measurement
	Average temperature (**T2M**)	T	Average daily temperature	seasonal / annual	°C
	Average precipitations (**MP**)	Prec	Average cumulative precipitations	seasonal / annual	mm
<1mm	Consecutive Dry Days (**CDD**)	Prec	Maximum number of consecutive days with daily precipitations under 1 mm	annual	[days]
>20 mm	Days with heavy rains (**R20**)	Prec	Number of days with precipitations over 20 mm	annual	[days/year]
Gelo	Frost Days (**FD**)	T	Number of days with minimum daily temperature lower than 0°C	annual	[days/year]
Estate	Summer Days (**SU95p**)	T	Number of days with maximum daily temperature higher than 29.2°C	annual	[days/year]
95° perc	95th percentile of precipitation (**P95**)	Prec	Summary of daily precipitations higher than the 95th percentile of the distribution of the daily rains on the basic climatologic period	annual	mm

Table 2.1. Climate indicators used in the current and future climatic analysis for the terrestrial areas of the Apulia Region

The climate results obtained from the dataset study were described with reference to the different spatial areas of Apulia represented in Figures 2.1.

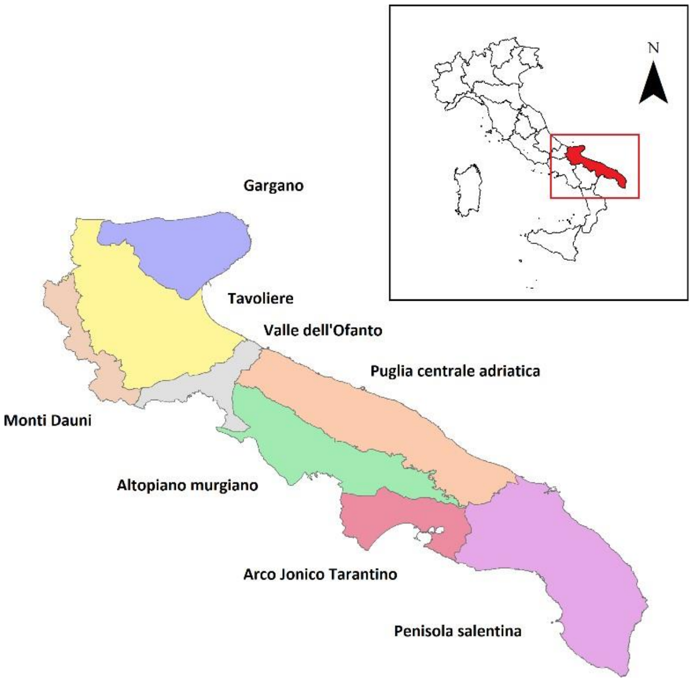


Figure 2.1. Regional spatial areas, areas and images developed by Piano Paesaggistico Territoriale Regionale, 2013

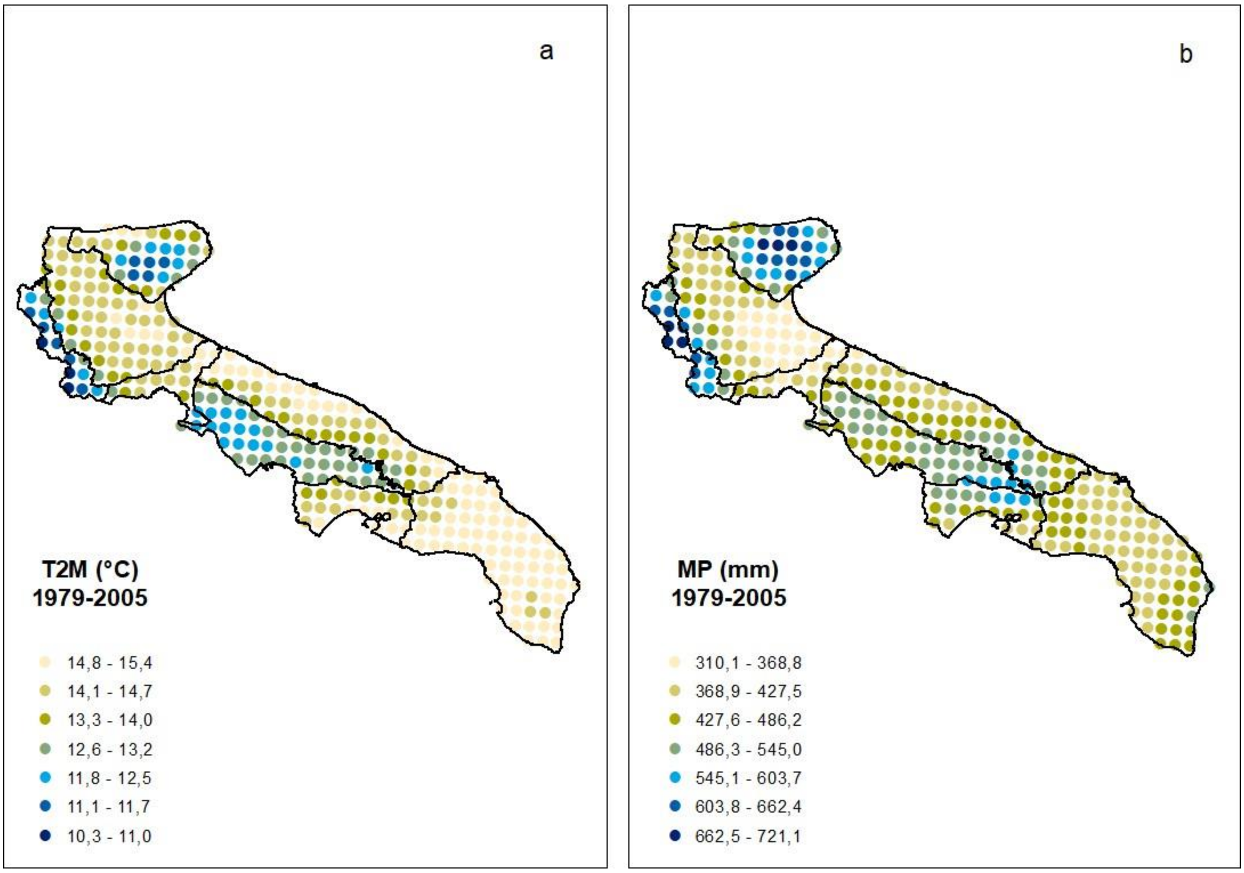
The first part of the climate analysis concerns the calculation of the annual average values of the seven climate indicators described in Table 2.1 for the reference period 1979-2005. To this end, Figures 2.2a, 2.2b, 2.2c, 2.2d, 2.2e, 2.2f, 2.2g report the spatial distribution of climate indicators in the Apulian territory.

In Apulia, the mean annual temperature values (T2M) vary from about 10.3°C to about 15.4°C, with the highest average values recorded on the Tavoliere, central Adriatic Apulia and the Salento peninsula (Figures 2.2a). The average annual number of summer days (SU95p) varies from fewer than 15 days/year to more than 80 days/year with the highest values on the Tavoliere (Figures 2.2f). The number of frost days (FD) varies from fewer than 10 days/year to more than 55 days/year, with the highest values distributed over the Monti Dauni, followed by the Altopiano delle Murge and the Gargano (Figures 2.2e). The Salento peninsula is the area least exposed to frost surges.

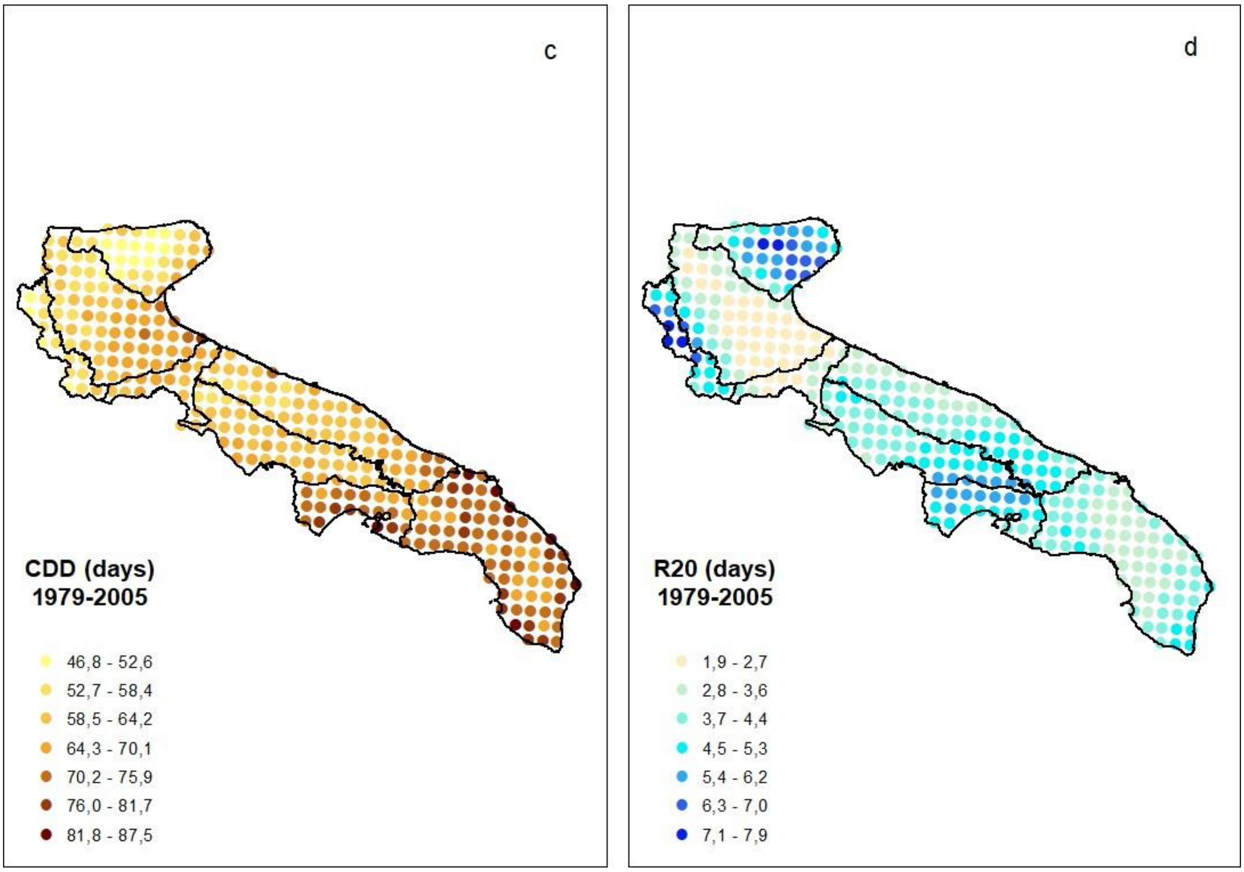
The annual mean cumulative precipitation (MP) records values between 310.10 mm/year and 721.10 mm/year, with the wettest areas being identified in the Monti Dauni, Gargano and the Altopiano delle Murge, while the driest areas are found in the Tavoliere and Valle dell’Ofanto and the Salento peninsula (Figures 2.2b). The number of days with heavy rainfall (R20), an indicator of extreme weather events, varies from about 1.8 days/year to about 7.9 days/year (Figures 2.2d).

The spatial distribution of this index shows the Gargano and Monti Dauni as the areas with the highest frequencies of heavy rainfall events, followed by the central and southern areas of the region, especially in the Arco Ionico Tarantino. Less exposed is the Tavoliere. The 95th percentile of precipitation (P95) is between about 17.6 mm and about 31.1 mm, with higher values found on the Arco Ionico Tarantino and limited areas of the Gargano (Figures 2.2g).

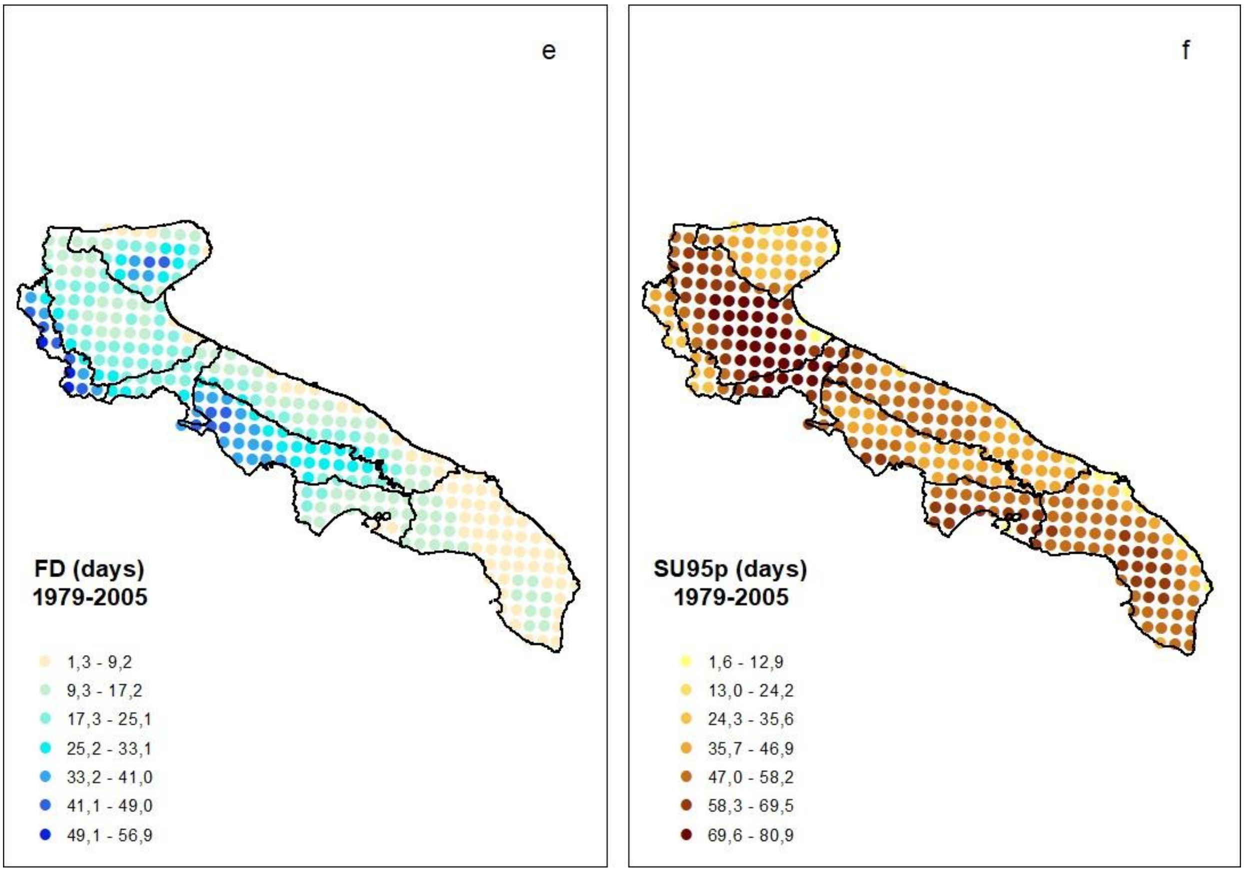
In Apulia, the maximum annual average value of consecutive dry days (CDD) stands at just over 87 days (Figures 2.2c). The spatial distribution of this indicator shows the Tavoliere area and especially the Salento peninsula as areas particularly exposed to long periods of drought. Gargano and Monti Dauni are found to be less exposed. Overall, the regional average Figures stands at about 65 consecutive days without rain.



Figures 2.2a-2.2b. Average annual distribution of average temperature (T2M) and average precipitations (MP), analysed in the historical period of reference 1979-2005.



Figures 2.2c-2.2d. Average annual distribution of consecutives dry days (CDD) and days with heavy rain (R20), analysed in the historical period of reference 1979-2005.



Figures 2.2e-2.2f. Average annual distribution of frost days (FD) and summer days (SU95p), analysed in the historical period of reference 1979-2005.

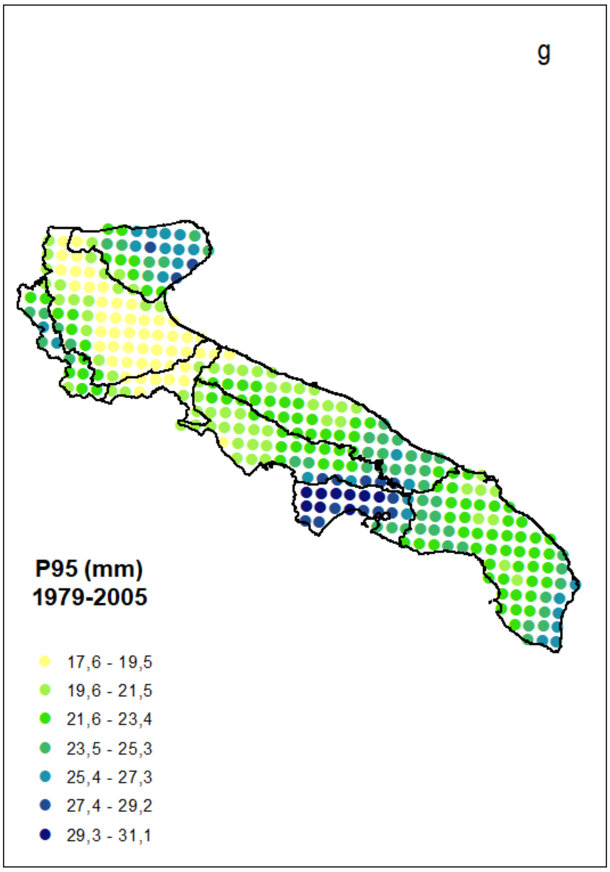


Figure 2.2g. Average annual distribution of the 95° percentile of precipitation (P95), analysed in the historical period of reference 1979-2005.

Figures 2.3a and Figures 2.3b show the seasonal average values of mean temperature and mean precipitation for the period 1979-2005, respectively. As regards average temperatures, the lowest values are recorded in all seasons along the region's main elevations: Monti Dauni, Gargano and the Altopiano delle Murge. Tavoliere, Salento and central Adriatic Apulia are affected by higher average temperature values. In terms of mean precipitation, the highest values are recorded during the winter season (December-February), followed by the spring period (March-May) and autumn (September-November), especially over the Monti Dauni, Gargano and Altopiano delle Murge. The summer season (June-August) is characterised by low precipitation values throughout the region, particularly on the Salento peninsula and Tavoliere.

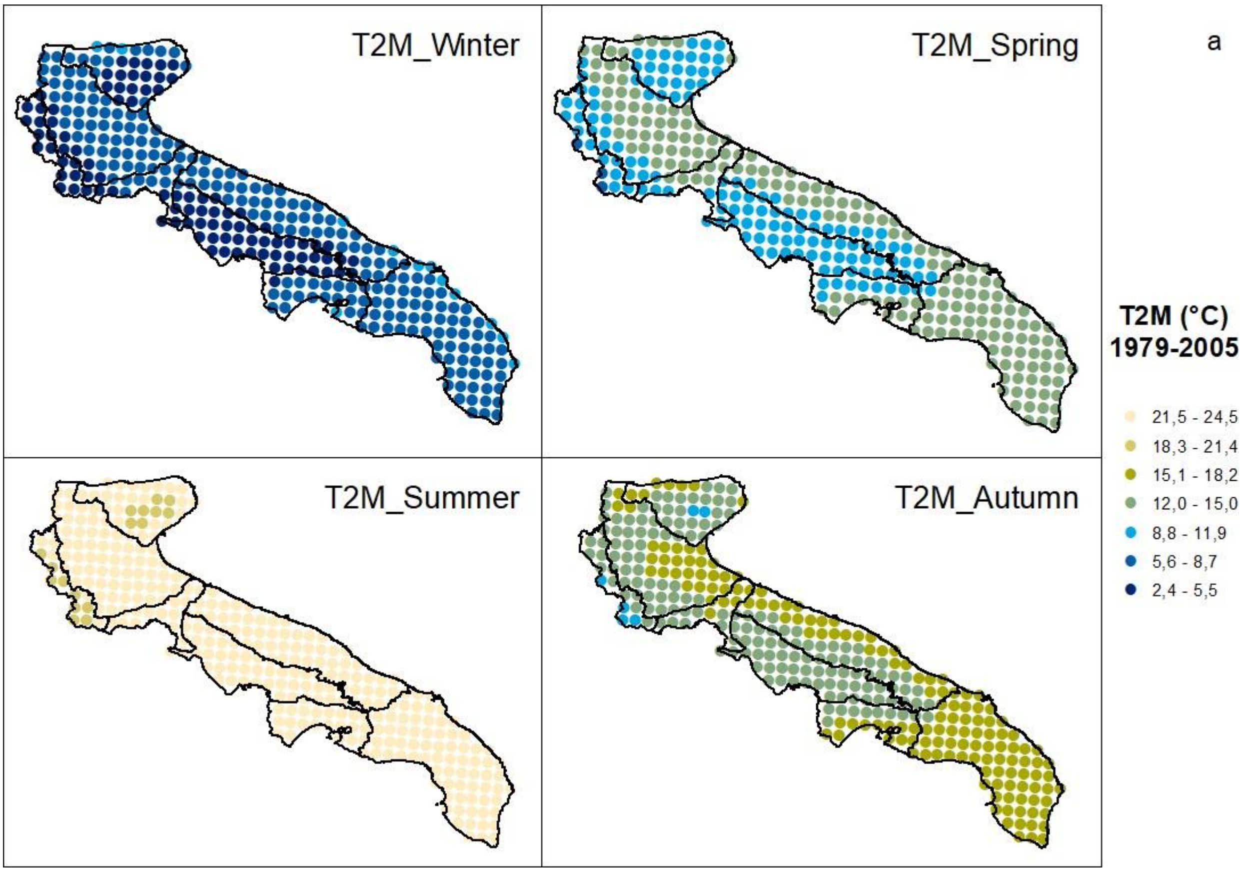


Figure 2.3a. Distribution of annual average values of average temperature (T2M), analysed in the historical period of reference 1979-2005.

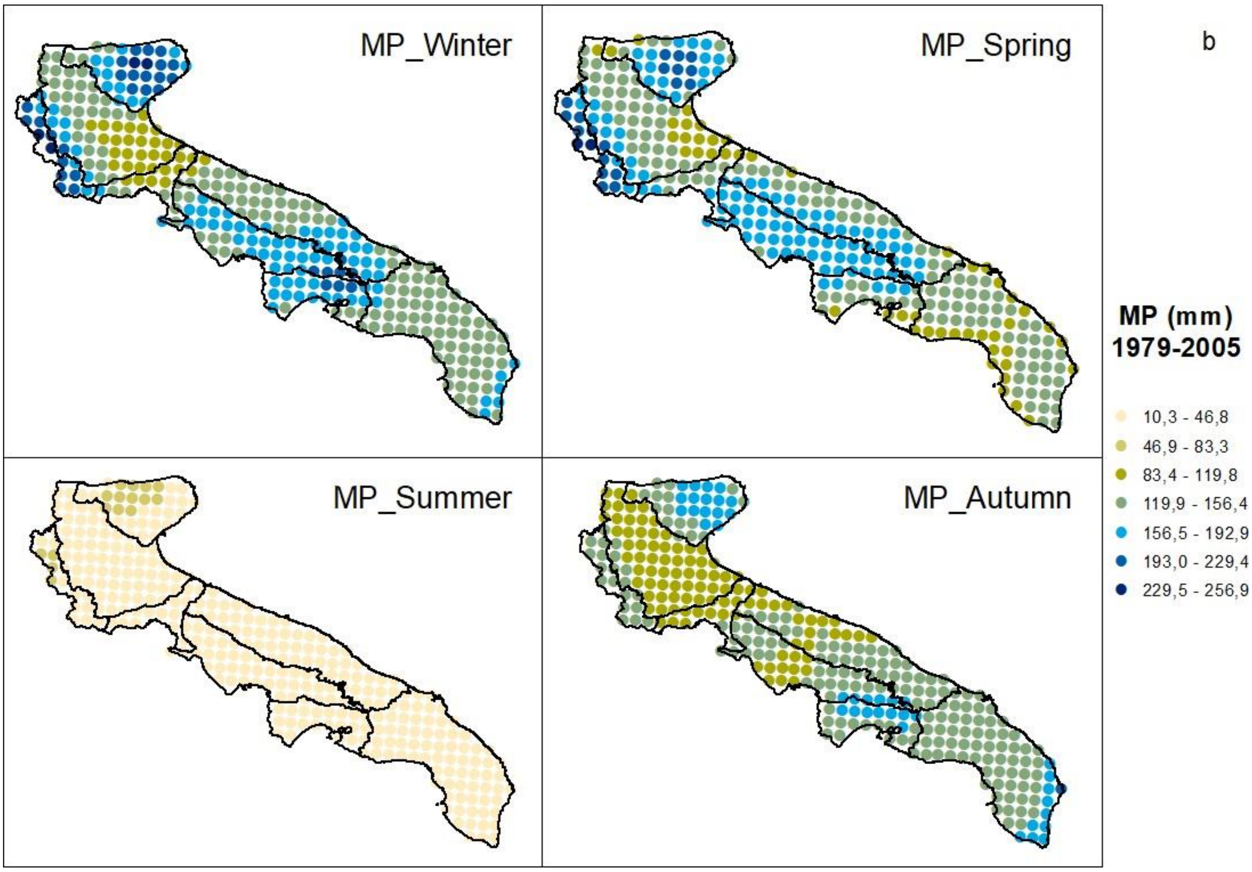


Figure 2.3b. Distribution of seasonal average values of average precipitations (MP), analysed in the historical period of reference 1979-2005.

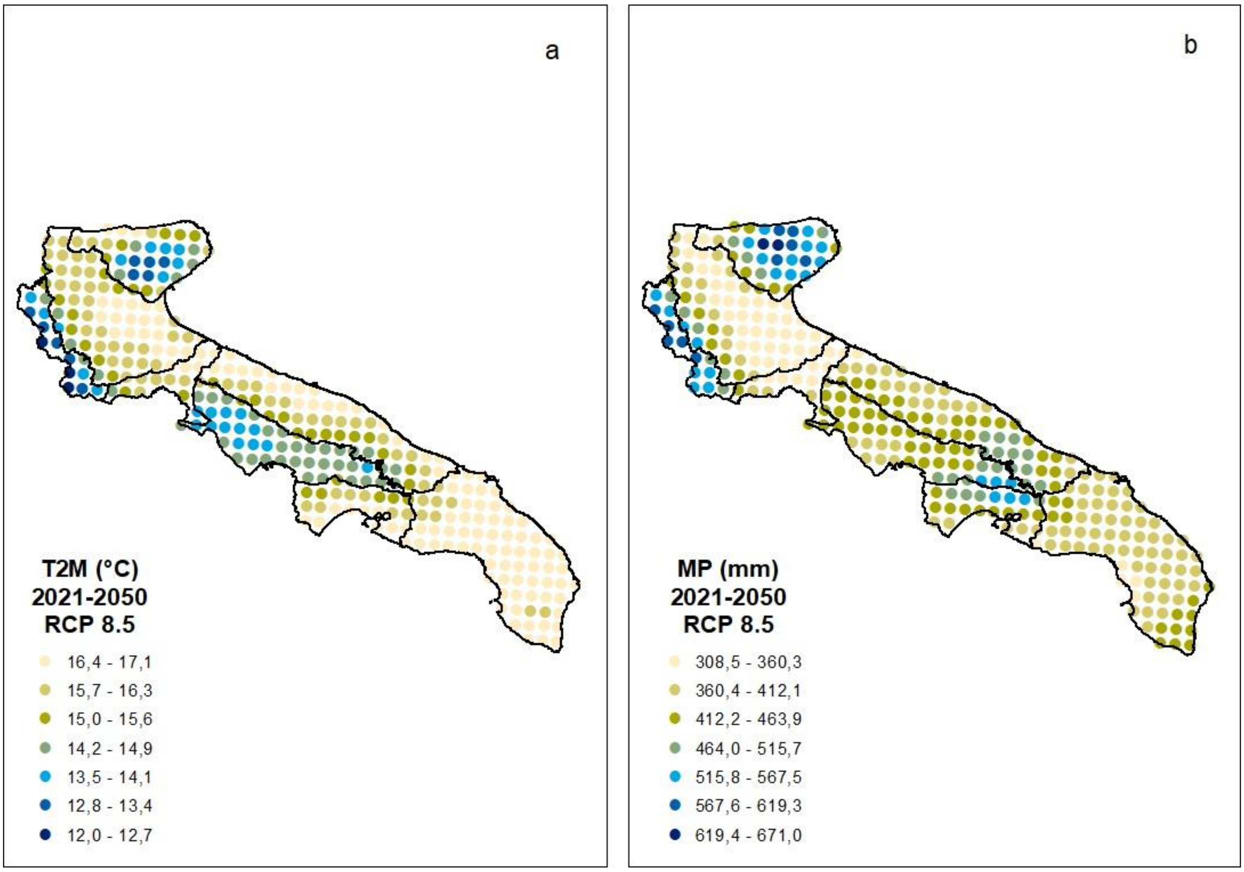
Table 2.2 shows the average, maximum and minimum annual values of the calculated indicators and the seasonal values of average temperature and average precipitation.

Looking at the data in Table 2.2, for average precipitation, the largest precipitation accumulations are concentrated in the winter season, followed by spring and autumn.

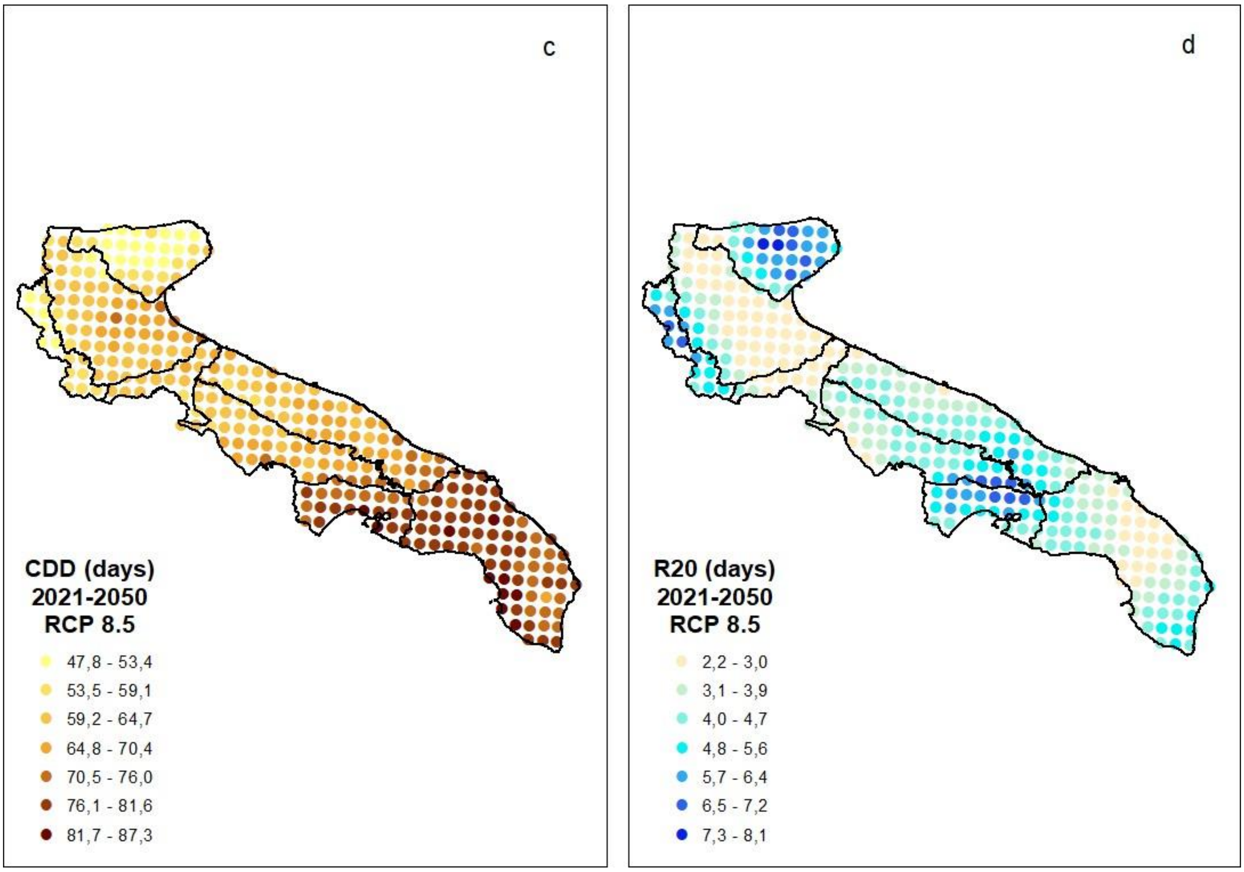
Indicator	Average Value	Maximum Value	Minimum Value
T2M (°C)	13.96	15.43	10.27
MP (mm)	460.94	721.10	310.10
CDD (days)	65.04	87.48	46.81
R20 (days)	4.05	7.89	1.85
FD (days)	18.32	56.93	1.30
SU95p (days)	50.95	80.85	1.59
P95 (mm)	22.48	31.14	17.59
T2M winter (°C)	6.23	9.73	2.37
T2M spring (°C)	11.72	13.18	8.02
T2M summer (°C)	23.00	24.54	19.56
T2M autumn (°C)	14.74	17.03	11.01
MP winter (mm)	154.35	256.94	95.91
MP spring (mm)	148.60	233.86	95.53
MP summer (mm)	27.79	66.91	10.26
MP autumn (mm)	130.19	194.51	88.40

Table 2.2. Average, maximum and minimum annual/seasonal values of climate indicators analysed for Apulia Region analysed for the historical period of reference 1979-2005.

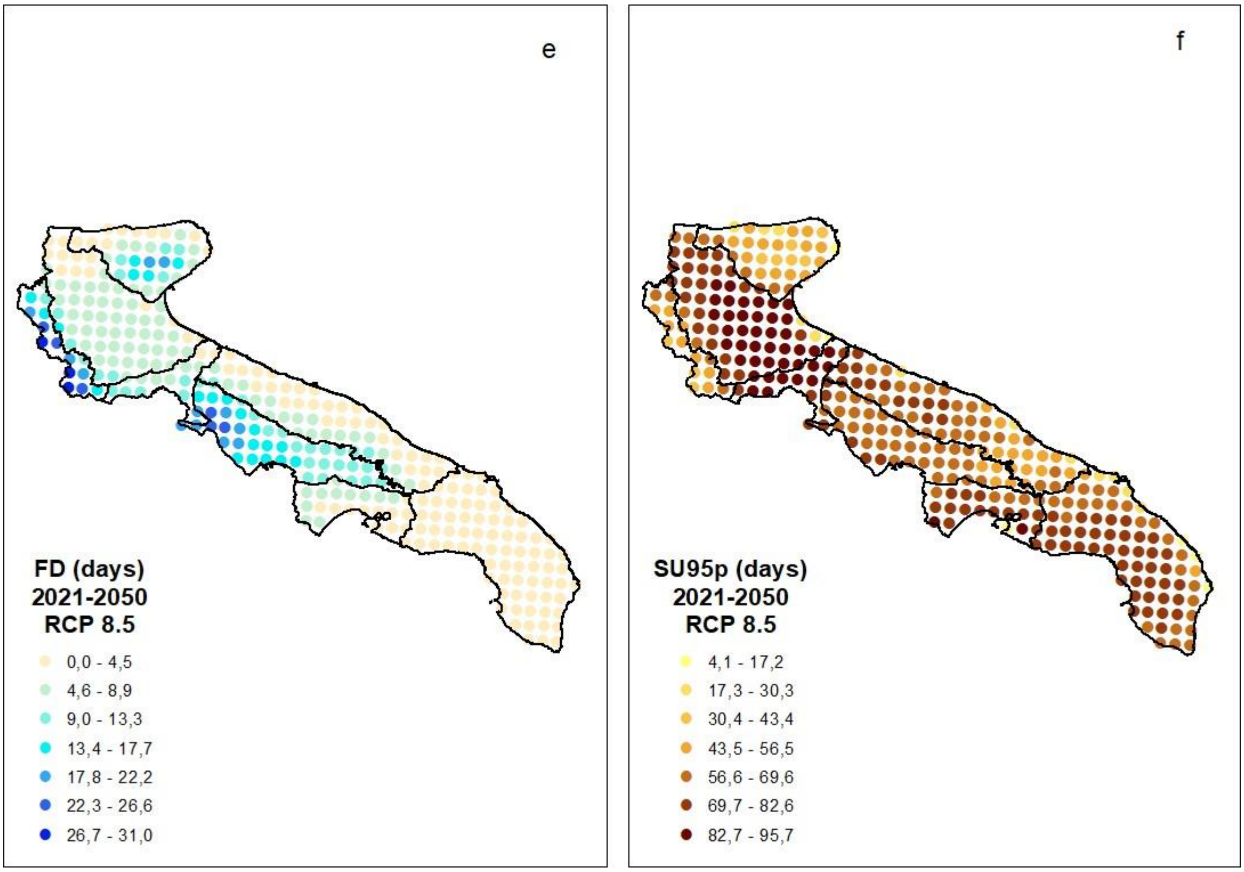
The climate indicators in Table 2.1 were used for the calculations for the RCP8.5 scenario, which are represented in Figures 2.4a, 2.4b, 2.4c, 2.4d, 2.4e, 2.4f, 2.4g. The spatial distribution of the climate indicators for the RCP4.5 scenario can be found in Figures 2.5a, 2.5b, 2.5c, 2.5d, 2.5e, 2.5f, 2.5g. For both future scenarios (RCP8.5 and RCP4.5), the period considered covers the years 2021-2050.



Figures 2.4a-2.4b. Average annual distribution of the average temperature (T2M) and average precipitation (MP), analysed on future period 2021-2050 for the climate scenario RCP8.5



Figures 2.4c-2.4d. Average annual distribution of consecutive dry days (CDD) and days with heavy rain (R20), analysed on future period 2021-2050 for the climate scenario RCP8.5



Figures 2.4e-2.4f. Average annual distribution of frost days (FD) and summer days (SU95p), analysed on future period 2021-2050 for the climate scenario RCP8.5

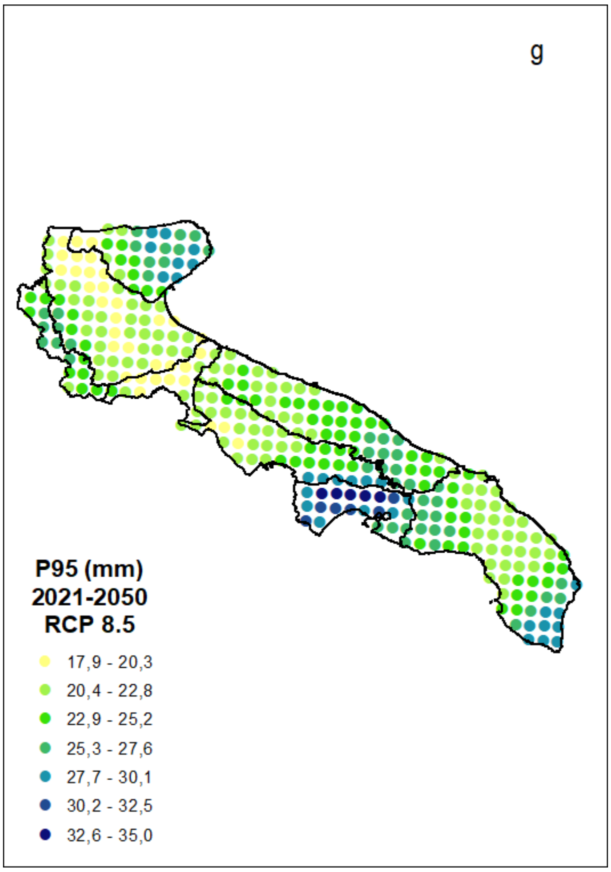
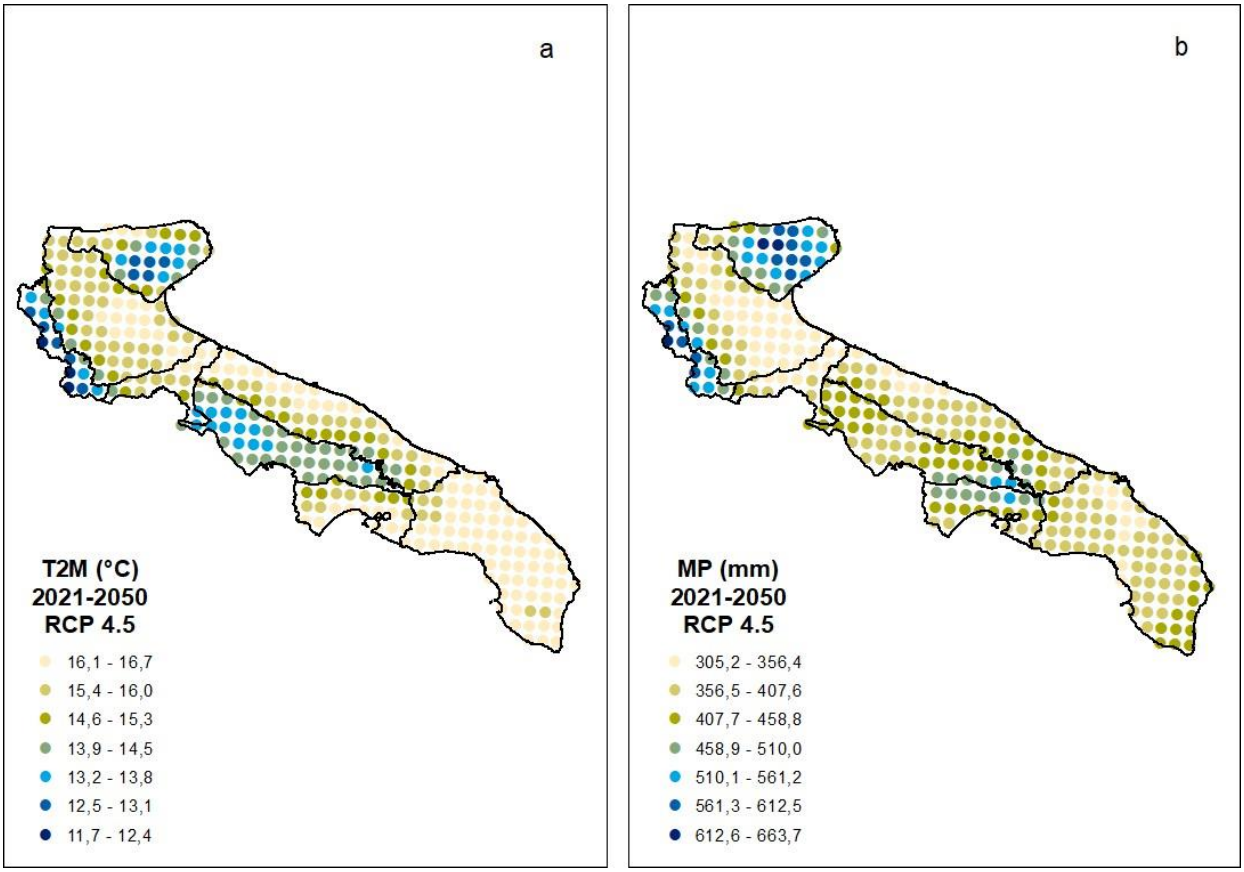
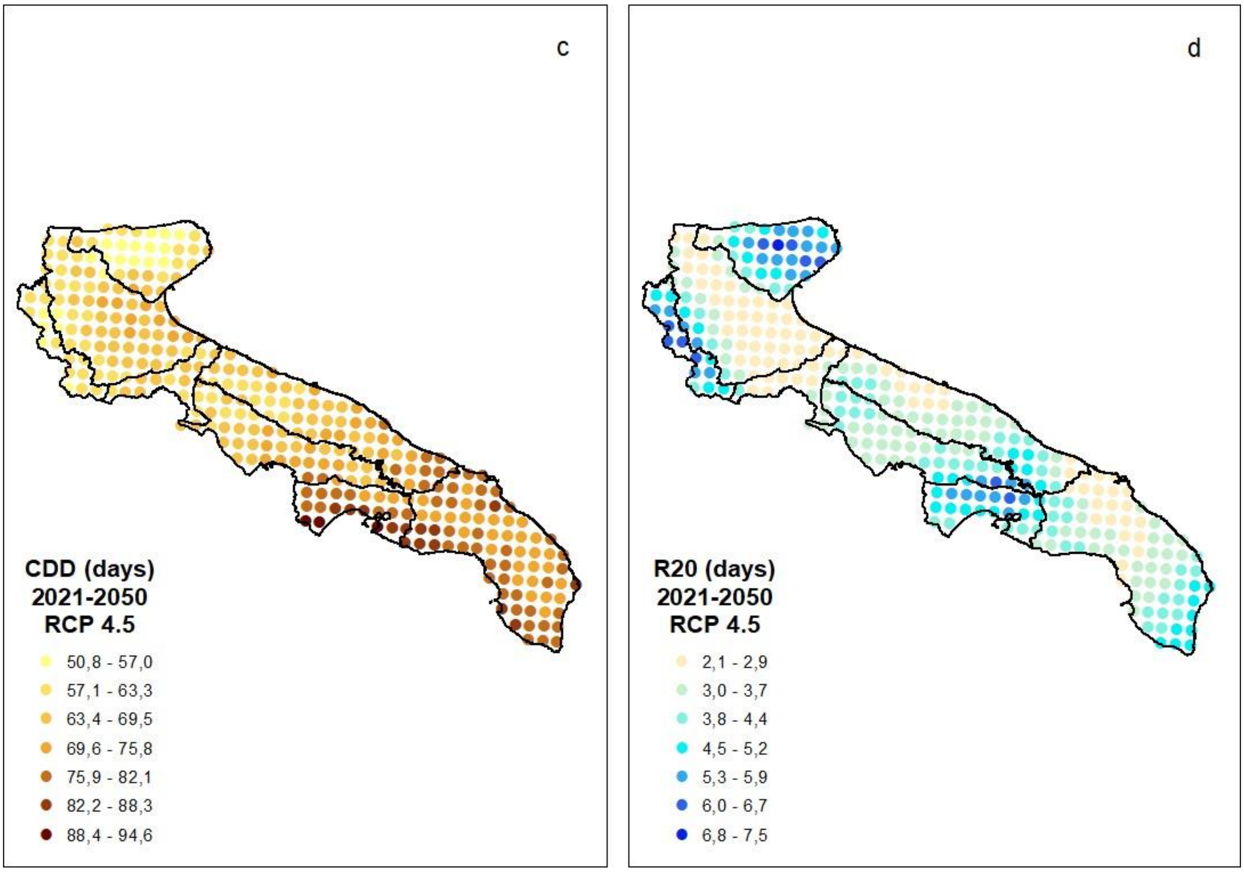


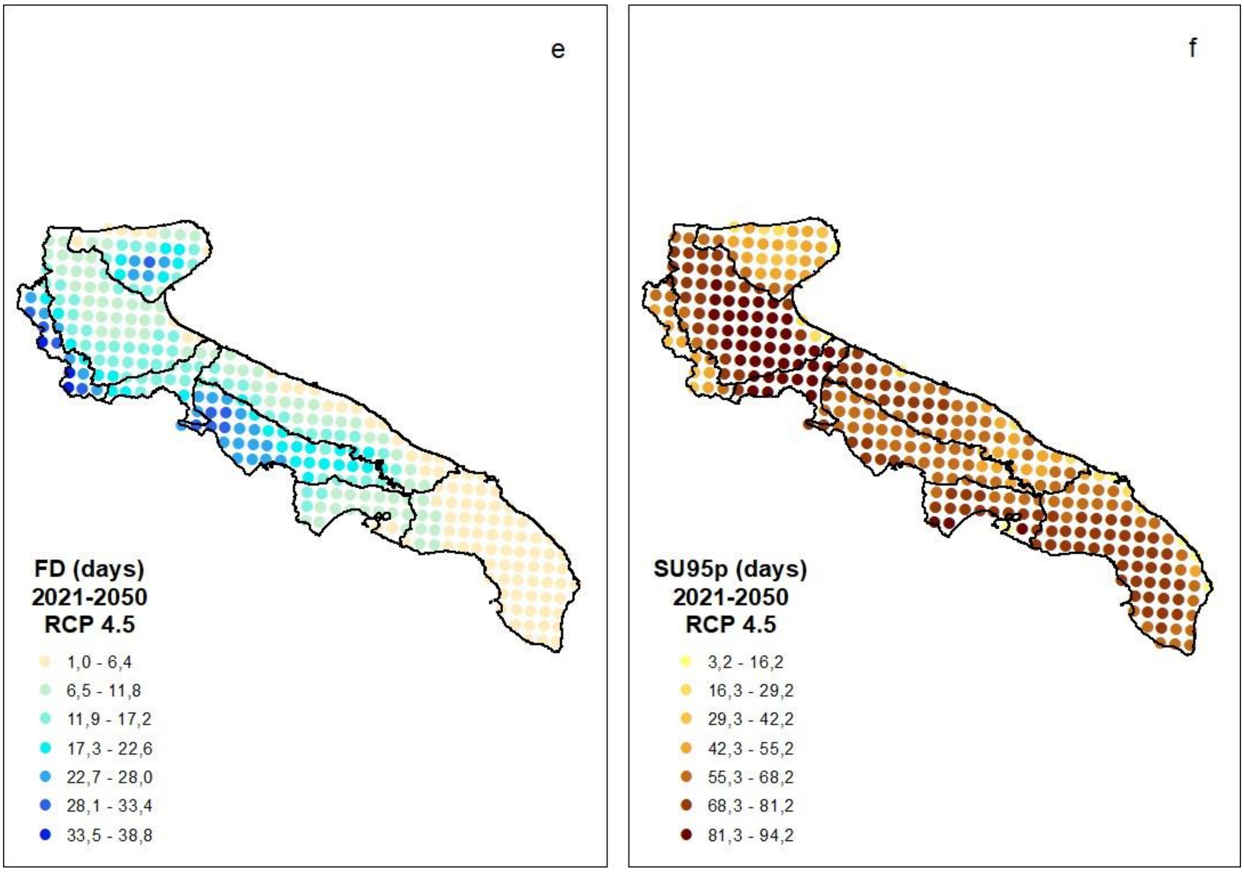
Figure 2.4g. Average annual distribution of the 95° percentile (P95), analysed on future period 2021-2050 for the climate scenario RCP8.5



Figures 2.5a-2.5b. Average annual distribution of average daily temperature (T2M) and average precipitation (MP), analysed on future period 2021-2050 for the climate scenario RCP4.5



Figures 2.5c-2.5d. Average annual distribution of consecutive dry days (CDD) and days with heavy rain (R20), analysed on future period 2021-2050 for the climate scenario RCP4.5.



Figures 2.5e-2.5f. Average annual distribution of frost days (FD) and summer days (SU95p), analysed on future period 2021-2050 for the climate scenario RCP4.5.

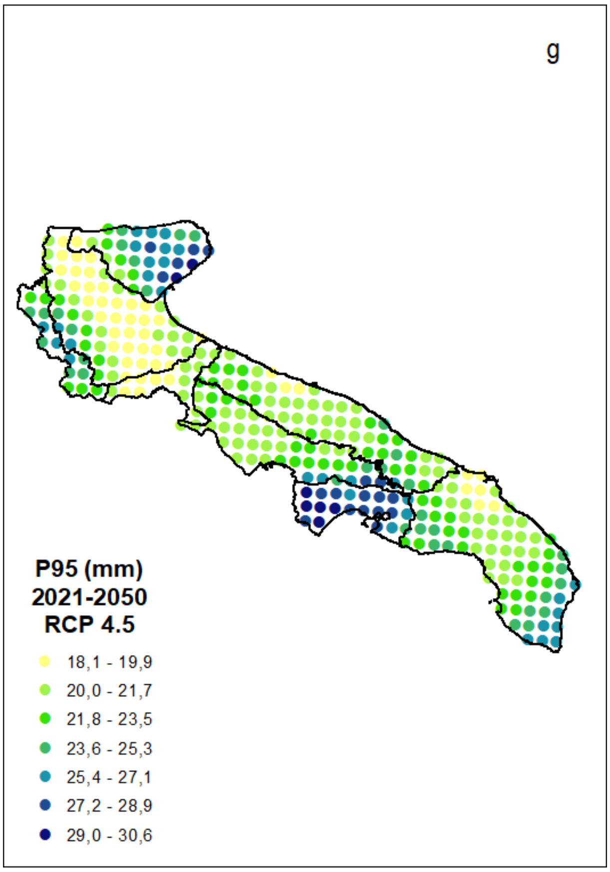


Figure 2.5g. Average annual distribution of the 95° percentile (P95), analysed on future period 2021-2050 for the climate scenario RCP4.5.

Figures 2.6a and Figures 2.6b respectively show the seasonal mean values of mean temperature and mean precipitation for the future climate scenario RCP8.5, while for future climate scenario RCP4.5, the seasonal mean values of mean temperature and mean precipitation are depicted in Figures 2.7a and Figures 2.7b.

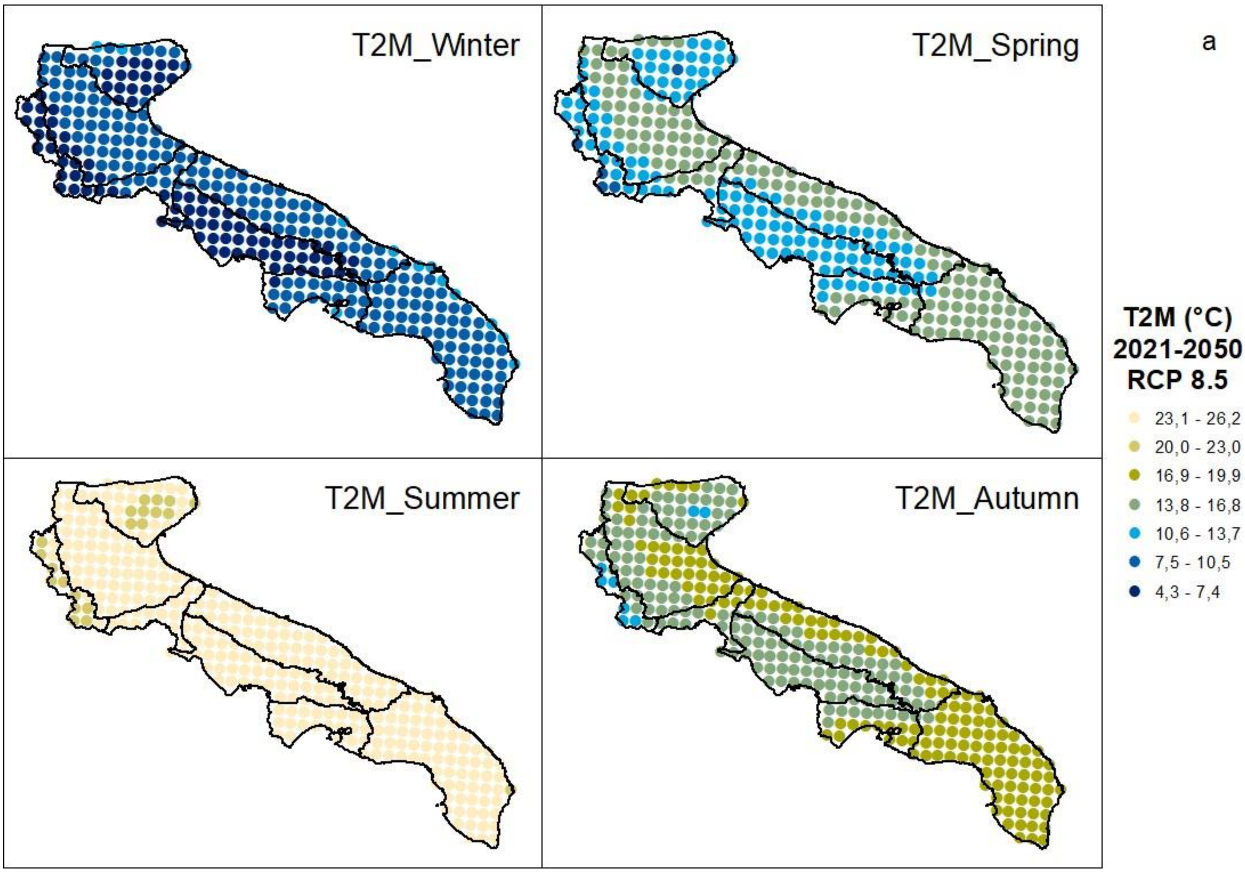


Figure 2.6a. Distribution of average seasonal daily temperature (T2M), analysed on future period 2021-2050 for the climate scenario RCP8.5.

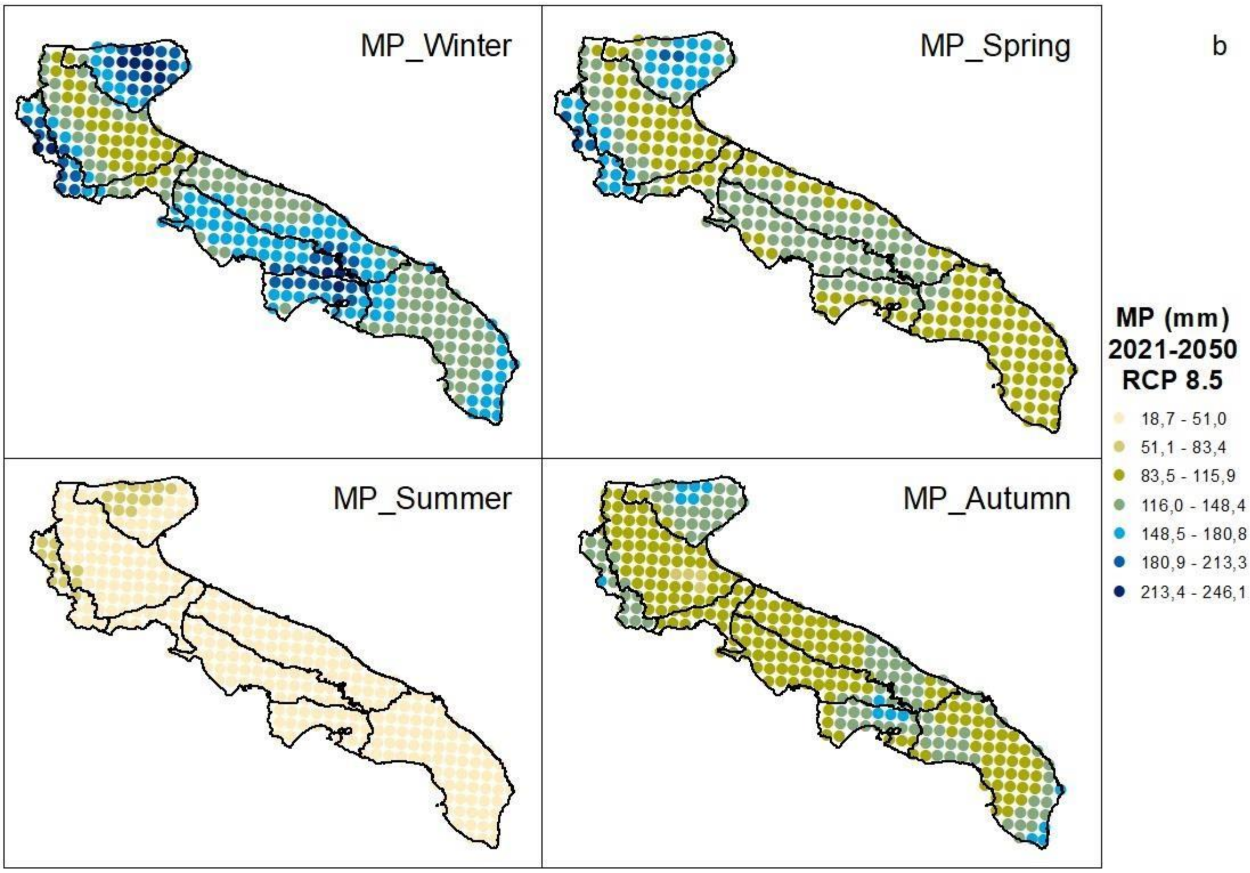


Figure 2.6b. Distribution of average seasonal precipitations (MP), analysed on future period 2021-2050 for the climate scenario RCP8.5.

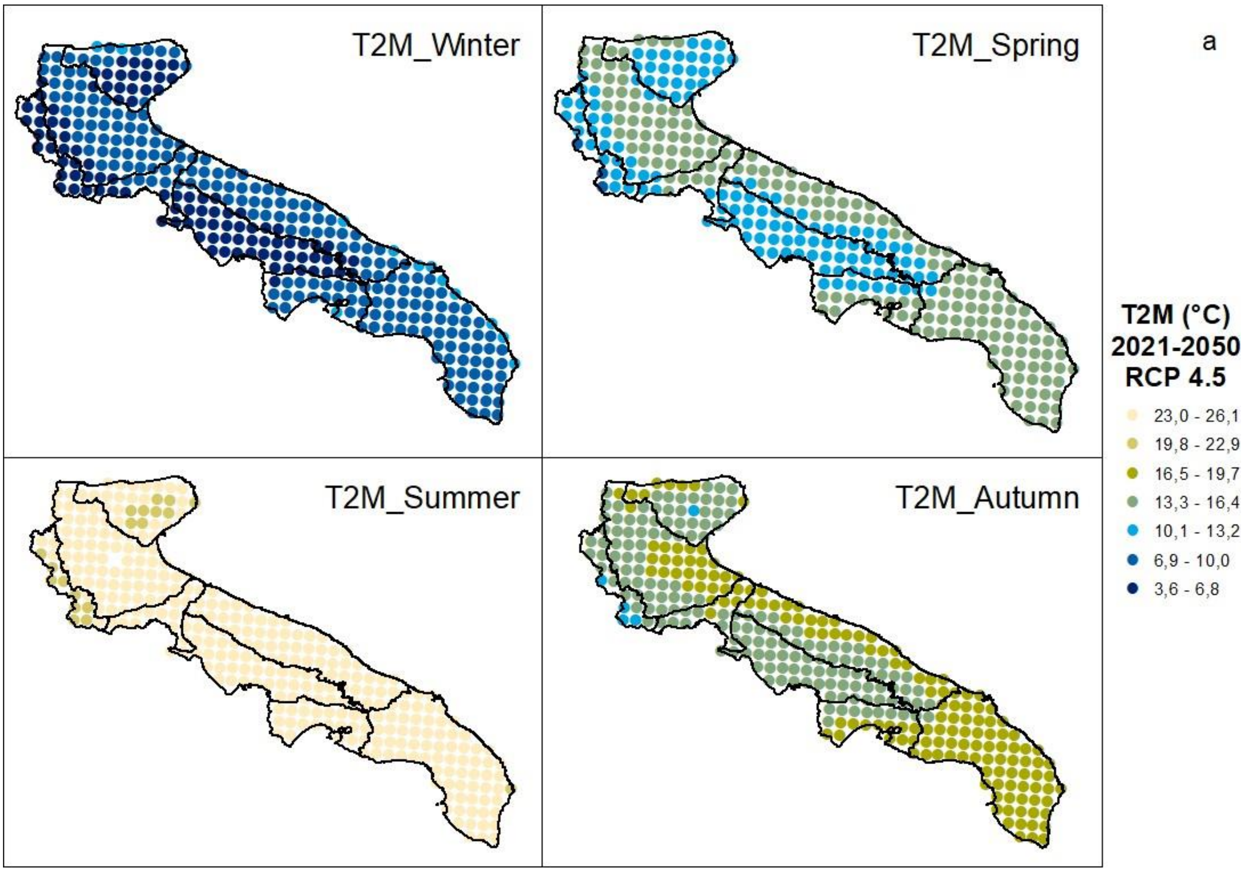


Figure 2.7a. Distribution of seasonal values of average temperature (T2M), analysed on future period 2021-2050 for the climate scenario RCP4.5.

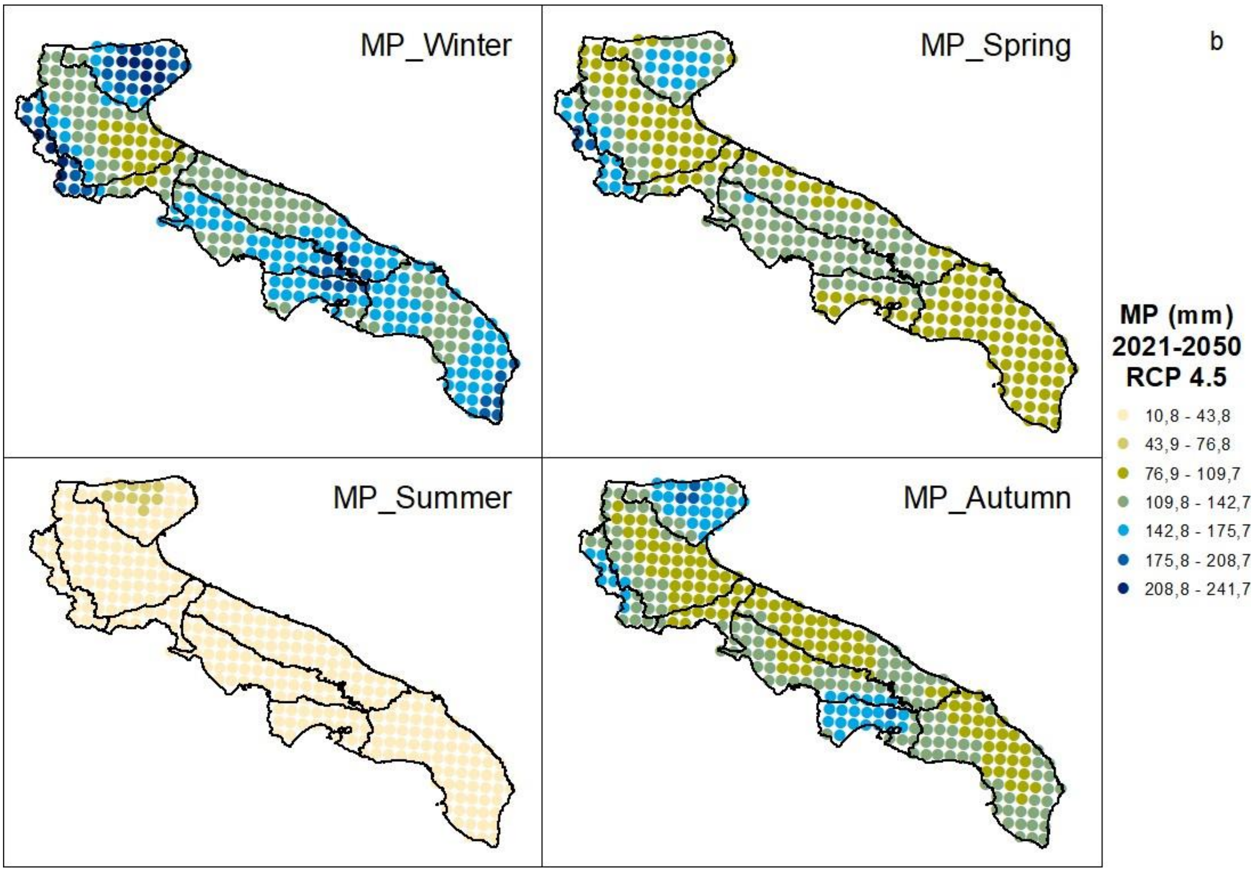


Figure 2.7b. Distribution of average seasonal values of average precipitation (MP), analysed on future period 2021-2050 for the climate scenario RCP4.5.

As can be seen in Figures 2.6a, 2.6b, 2.7a and 2.7b, the seasonal distribution of mean temperatures and mean precipitation does not change substantially in terms of spatial distribution. If we also examine Figures 2.3a and 2.3b, in relation to the historical period (1979-2005), it is clear that the wettest and coolest areas in the region will continue to be located in the Monti Dauni, Gargano and Altopiano delle Murge for both future scenarios (2021-2050). The hottest and driest areas will still be Tavoliere and the Salento peninsula. As observed in the future projections of seasonal mean temperature and precipitation, the spatial distribution of the mean values of the calculated indicators does not vary significantly compared to the historical period 1979-2005.

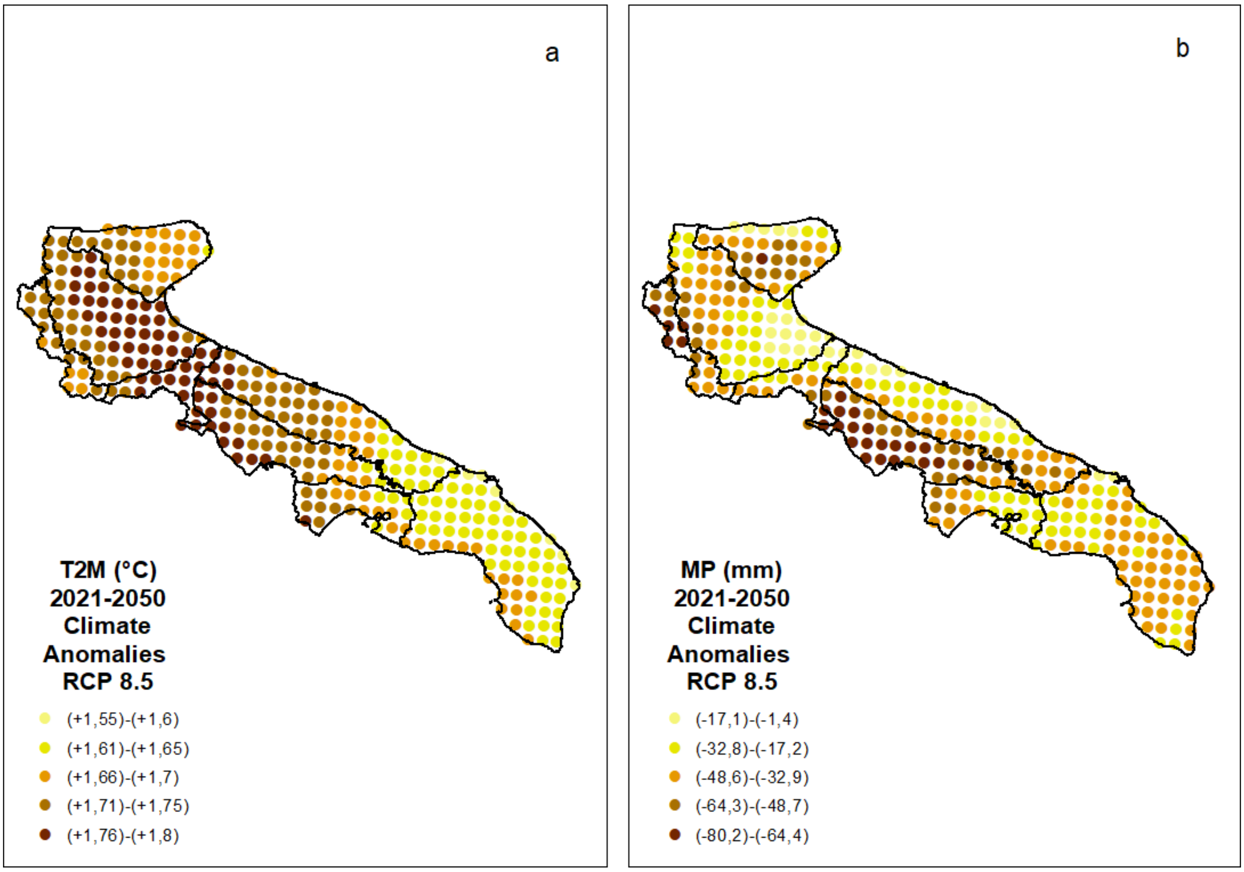
Table 2.3 compares the estimated mean, maximum and minimum values for climate parameters calculated from the dataset, for the RCP8.5 and RCP4.5 scenarios relative to the period 2021-2050.

Indicator	Average Value		Maximum Value		Minimum Value	
	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5
T2M (°C)	15.66	15.31	17.05	16.70	11.97	11.66
MP (mm)	422.75	412.33	671.04	663.66	308.53	305.17
CDD (days)	67.08	69.02	87.27	94.57	47.80	50.77
R20 (days)	4.06	3.70	8.07	7.47	2.20	2.13
FD (days)	6.71	11.99	31.00	38.77	0.03	0.97
SU95p (days)	65.59	64.72	95.73	94.17	4.13	3.23
P95 (mm)	23.66	22.45	34.95	30.65	17.91	18.12
T2M winter (°C)	8.08	7.42	11.46	10.95	4.26	3.56
T2M spring (°C)	13.41	13.07	14.73	14.38	9.69	9.40
T2M summer (°C)	24.56	24.50	26.17	26.12	21.10	21.09
T2M autumn (°C)	16.46	16.13	18.60	18.30	12.69	12.44
MP winter (mm)	151.71	149.99	246.07	241.71	105.39	97.74
MP spring (mm)	121.54	116.27	190.64	183.12	83.72	80.09
MP summer (mm)	36.69	25.41	73.11	70.74	18.74	10.78
MP autumn (mm)	112.82	120.66	165.28	188.30	80.50	96.44

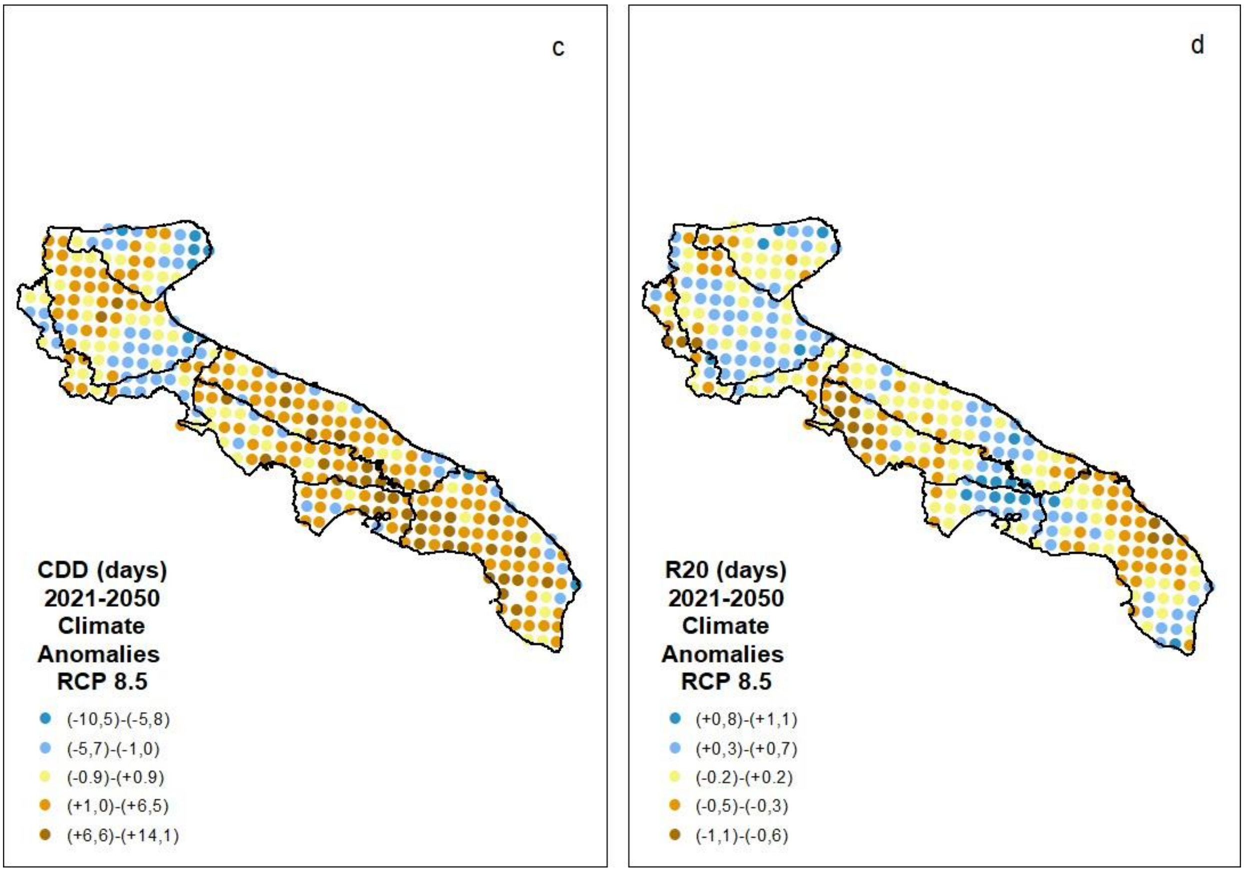
Table 2.3. *Average, maximum and minimum annual/seasonal values of climate indicators analysed for Apulia Region for future period of reference 2021-2050 for climate scenarios RCP8.5 and RCP4.5.*

The anomalies of the climate indicators described above for the future period 2021-2050 (Figures 2.4a to Figures 2.7b), compared to the historical reference period 1979-2005 (Figures 2.2a to Figures 2.3b), allow us to assess the average climate change trend at a regional level.

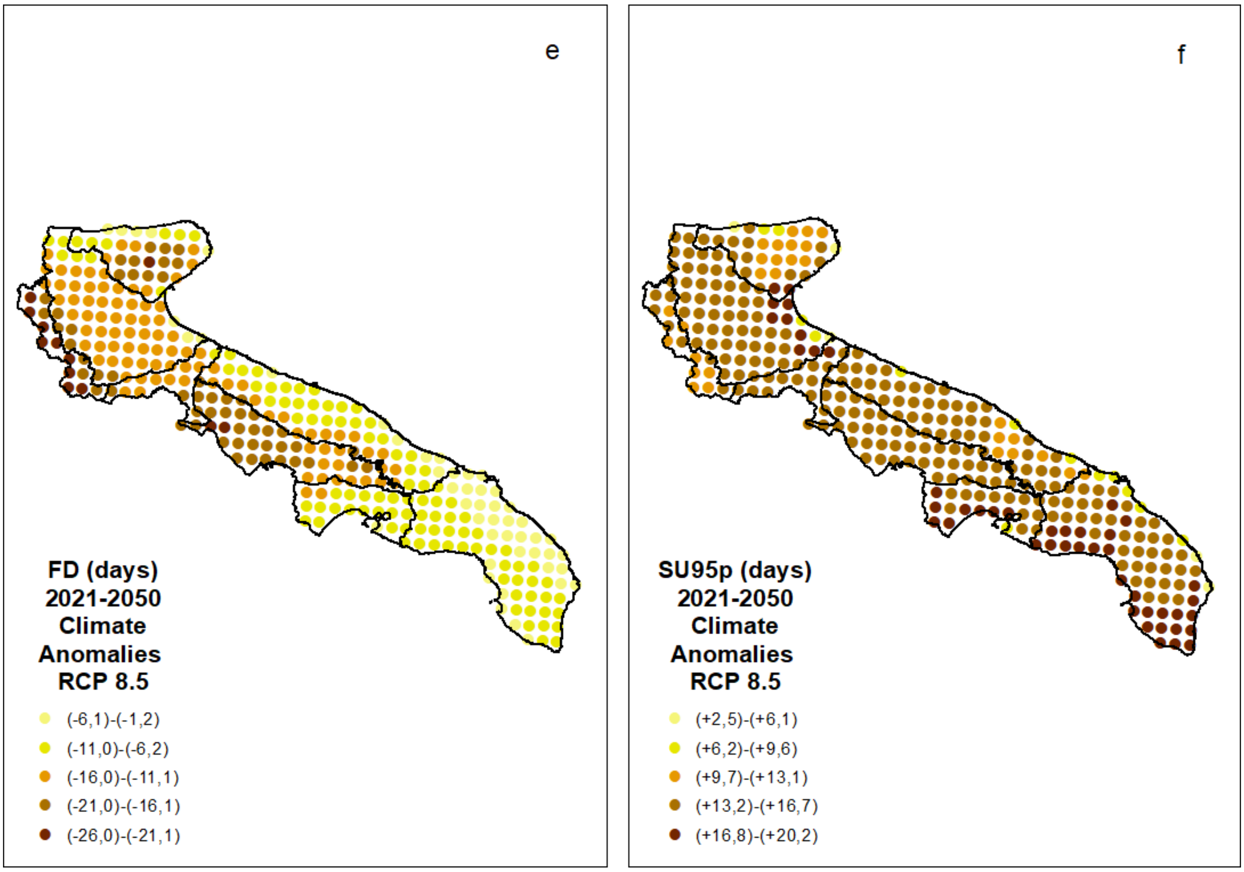
Figures 2.8a, 2.8b, 2.8c, 2.8d, 2.8e, 2.8f, 2.8g and Figures 2.9a, 2.9b, 2.9c, 2.9d, 2.9e, 2.9f, 2.9g show the climate anomaly maps for all climate indicators described in Table 2.1, according to the RCP8.5 and RCP4.5 scenarios, respectively.



Figures 2.8a-2.8b. Annual average distribution of anomalies of average temperature (T2M) and average precipitation (MP), calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP8.5.



Figures 2.8c-2.8d. Annual average distribution of anomalies of consecutive dry days (CDD) and days of heavy rain (R20), calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP8.5.



Figures 2.8e-2.8f. Annual average distribution of anomalies of frost days (FD) and summer days (SU98p), calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP8.5.

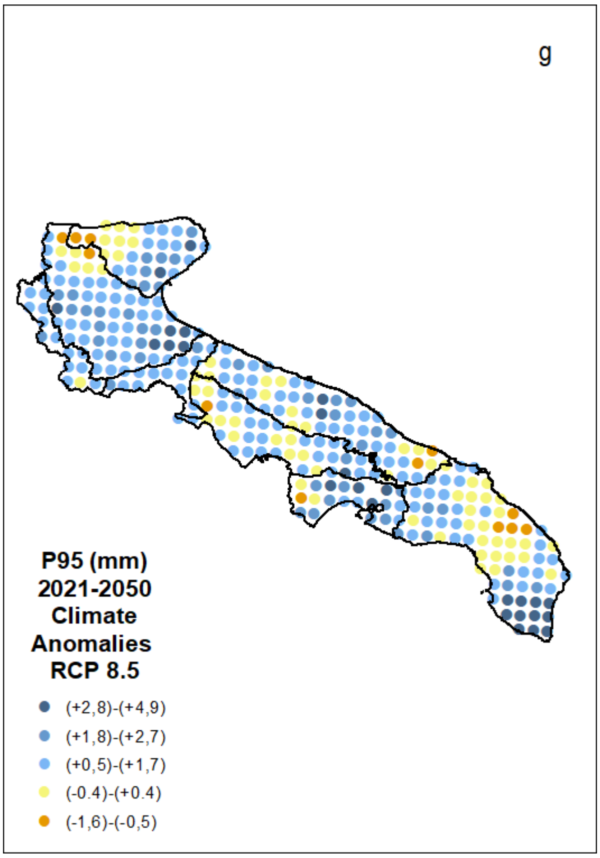
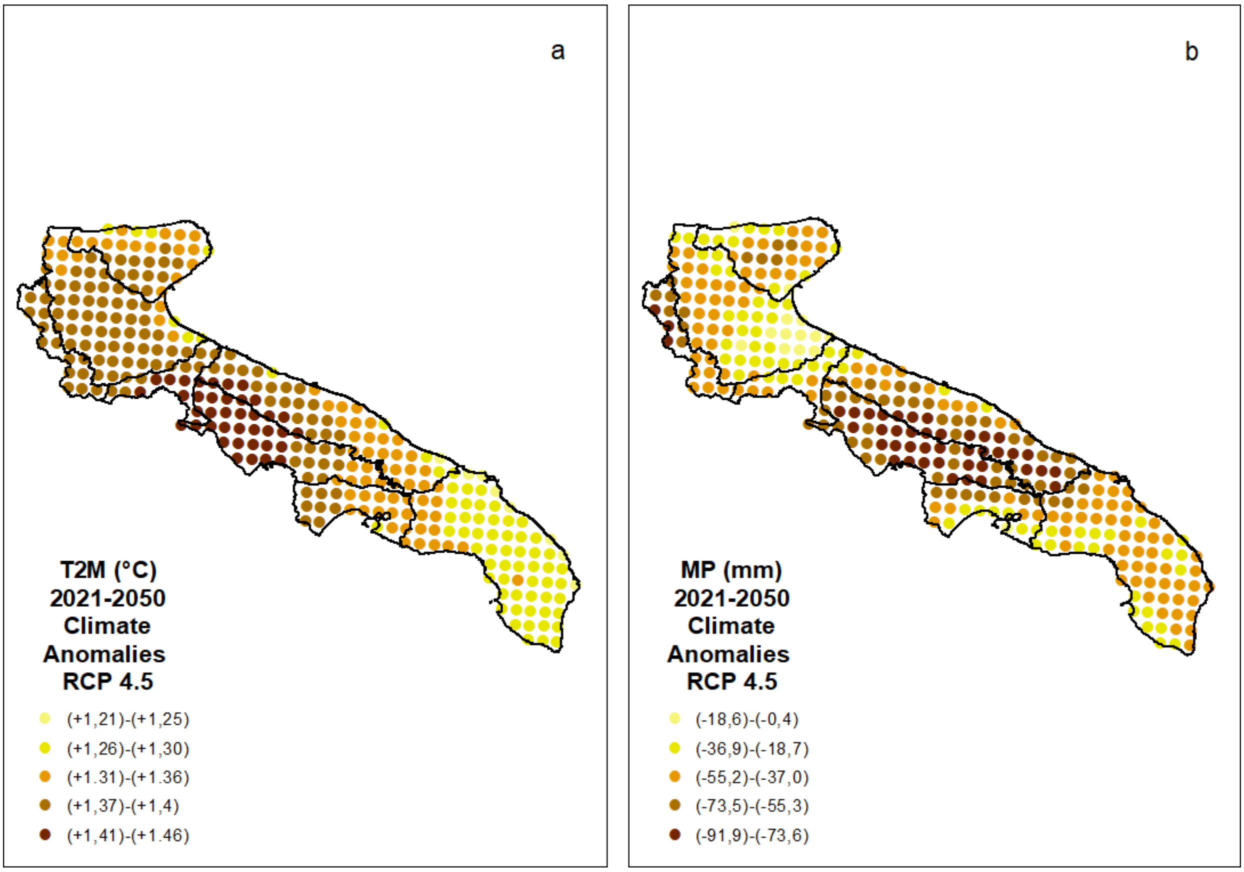
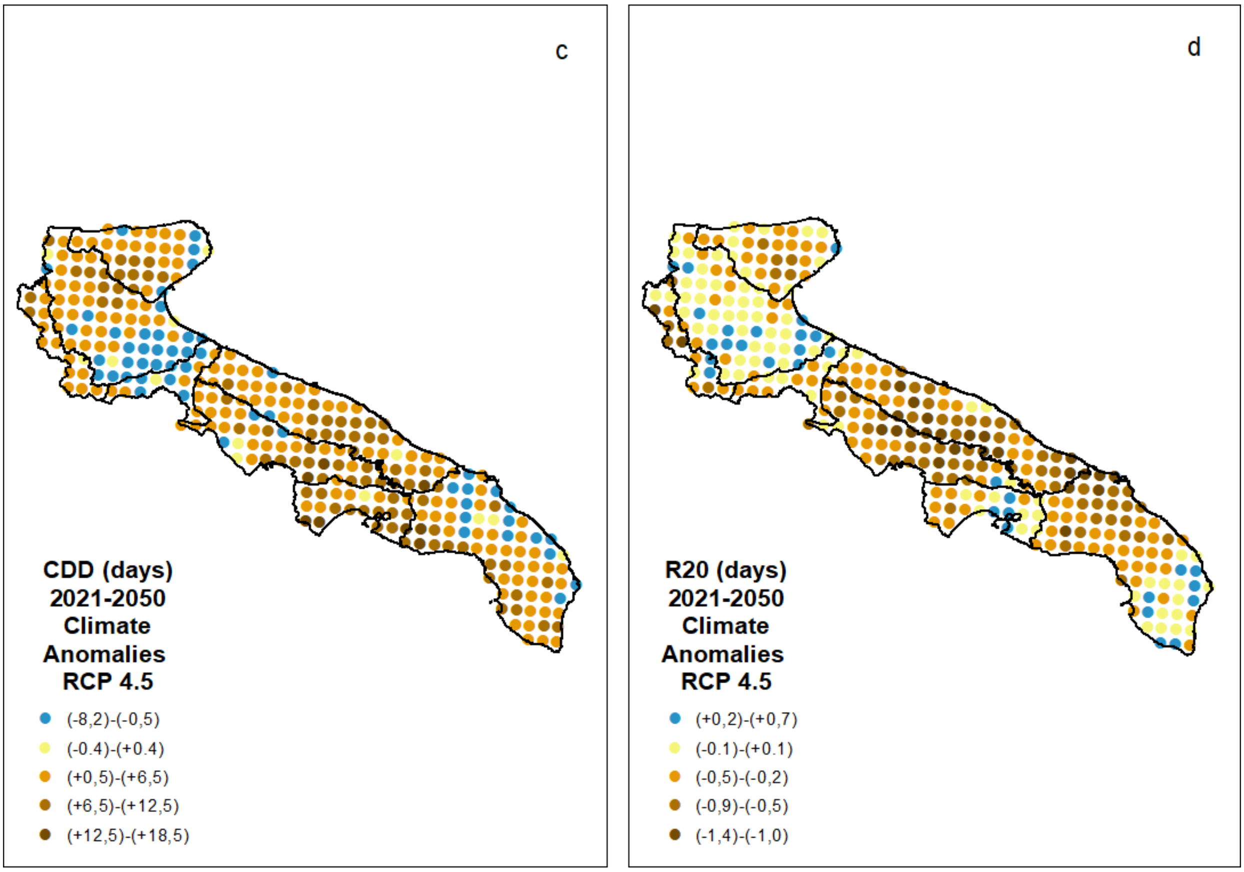


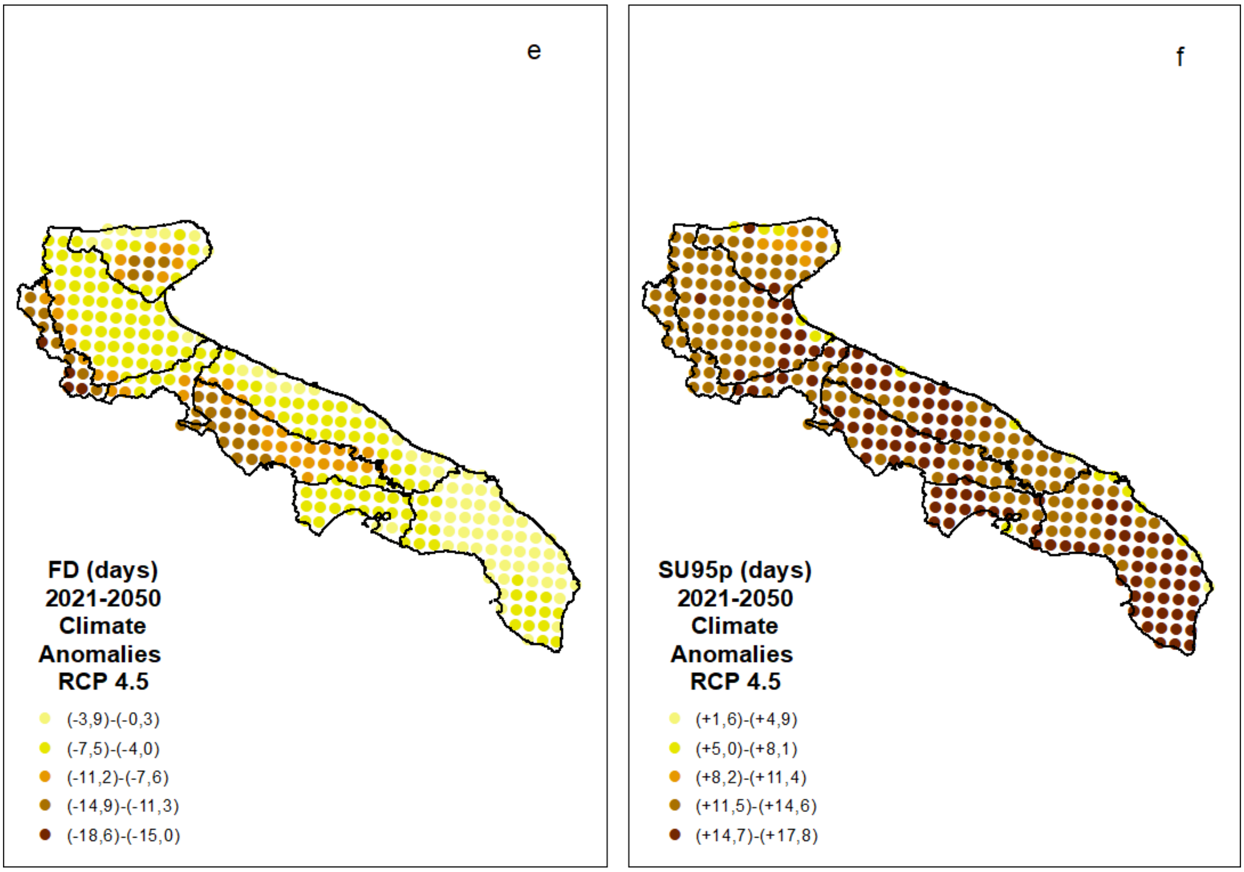
Figure 2.8g. Annual average distribution of anomalies in 95° percentile (P95), calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP8.5.



Figures 2.9a-2.9b. Annual average distribution of anomalies of average temperature (T2M) and average precipitation (MP), calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP4.5.



Figures 2.9c-2.9d. Annual average distribution of anomalies of consecutive dry days (CDD) and days of heavy rain (R20) calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP4.5.



Figures 2.9e-2.9f. Annual average distribution of anomalies of frost days (FD) and summer days (SU95p), calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP4.5.

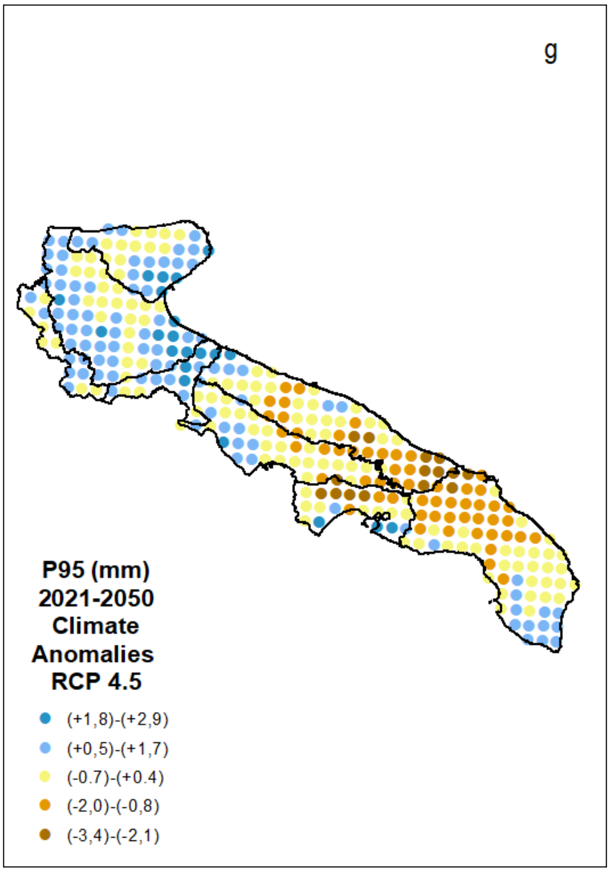


Figure 2.9g. Annual average distribution of anomalies of 95° percentile (P95), calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP4.5.

The analysis of climate anomalies projects a general increase in mean annual temperatures (T2M) across the region, with an average increase of 1.7°C in the RCP8.5 scenario (Figures 2.8a), and an average increase of 1.36°C in the RCP4.5 scenario (Figures 2.9a). Similarly, an increase in summer days (SU95p) is projected over the entire region, with a maximum of 20 days/year in the RCP8.5 scenario (Figures 2.8f) and almost 18 days/year in the RCP4.5 scenario (Figures 2.9f), particularly for the Salento peninsula and central Adriatic Apulia. Frost days (FD) show a consistent decrease, which is more pronounced in the RCP8.5 scenario.

In both future scenarios, the annual mean cumulative precipitation (MP) shows a reduction, corresponding to about -80 mm and about -92 mm for the RCP8.5 (Figures 2.8b) and RCP4.5 (Figures 2.9b) scenarios, respectively. Central Adriatic Apulia turns is the area with the greatest decrease in rainfall. The days of intense precipitation (R20) show a negligible increase in the RCP8.5 scenario (Figures 2.8d) and a slight decrease in the RCP4.5 scenario (Figures 2.9d). The index of extreme rainfall events (P95) marks a variable percentage increase; in the RCP8.5 scenario (Figures 2.8g) the percentage increases are slightly higher (plus about 5 mm) distributed mainly over the Tavoliere and lower Valle dell'Ofanto and the south of the Salento peninsula.

In the RCP4.5 scenario (Figures 2.9g), the greatest increases (plus about 3 mm) occur in the lower Tavoliere, Monti Dauni, Gargano, Altopiano delle Murge, and southern Salento peninsula.

The maximum number of consecutive dry days (CDD) shows an increase in both future scenarios. In the RCP8.5 scenario (Figures 2.8c), a maximum increase of 14 days is expected. A maximum increase of 18 consecutive dry days is observed in the RCP4.5 scenario (Figures 2.9c). Generally speaking, a large part of the regional territory may be exposed to rainfall-free periods that last even longer than three consecutive months (Giannakopoulos et al., 2009; Cramer et al., 2018).

Figures 2.10a and 2.10b show the climate anomalies of seasonal mean temperature, relative to the two climate scenarios considered (RCP8.5 and RCP4.5). The trends of the climatic anomalies of mean seasonal precipitation under the two scenarios mentioned above are shown in Figures 2.11a and 2.11b.

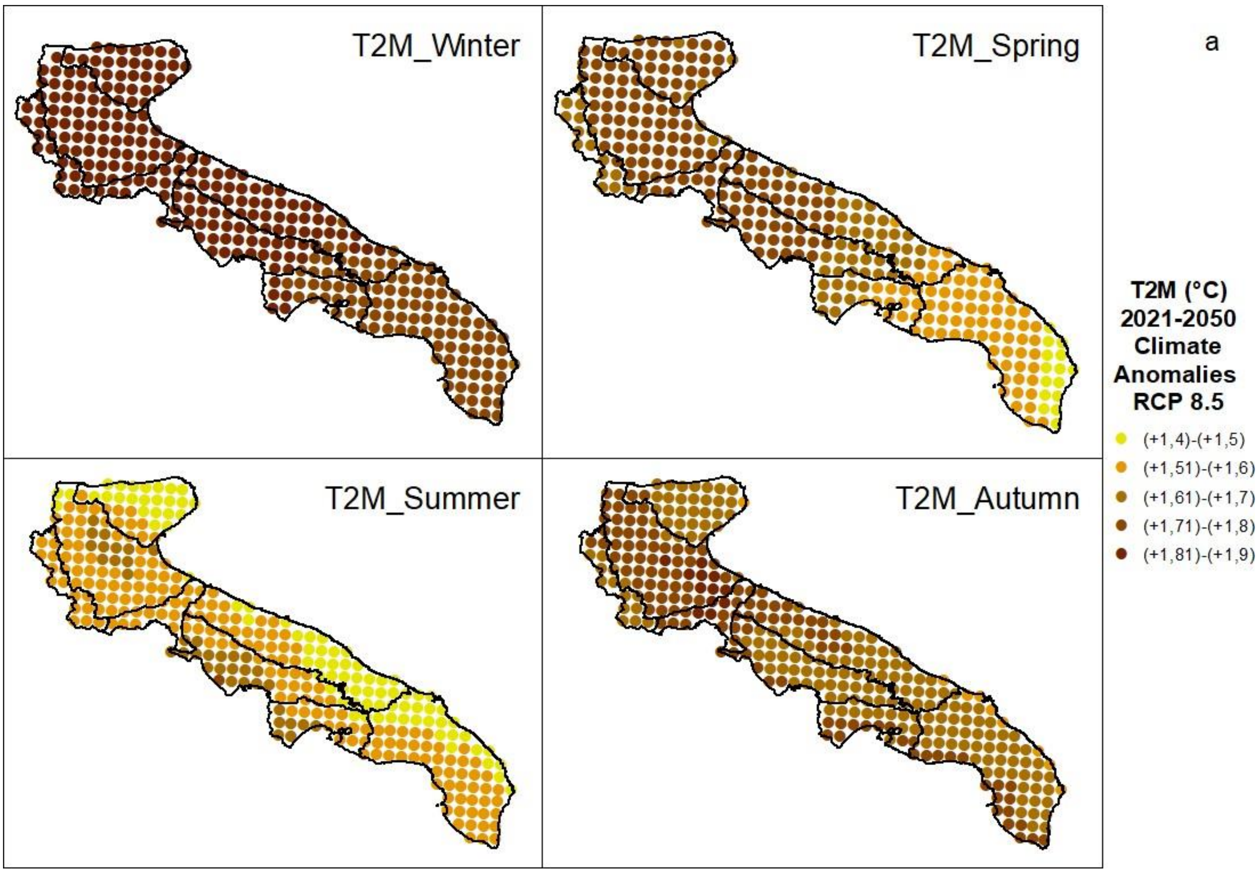


Figure 2.10a. Distribution of anomalies of average seasonal temperature (T2M), calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP8.5.

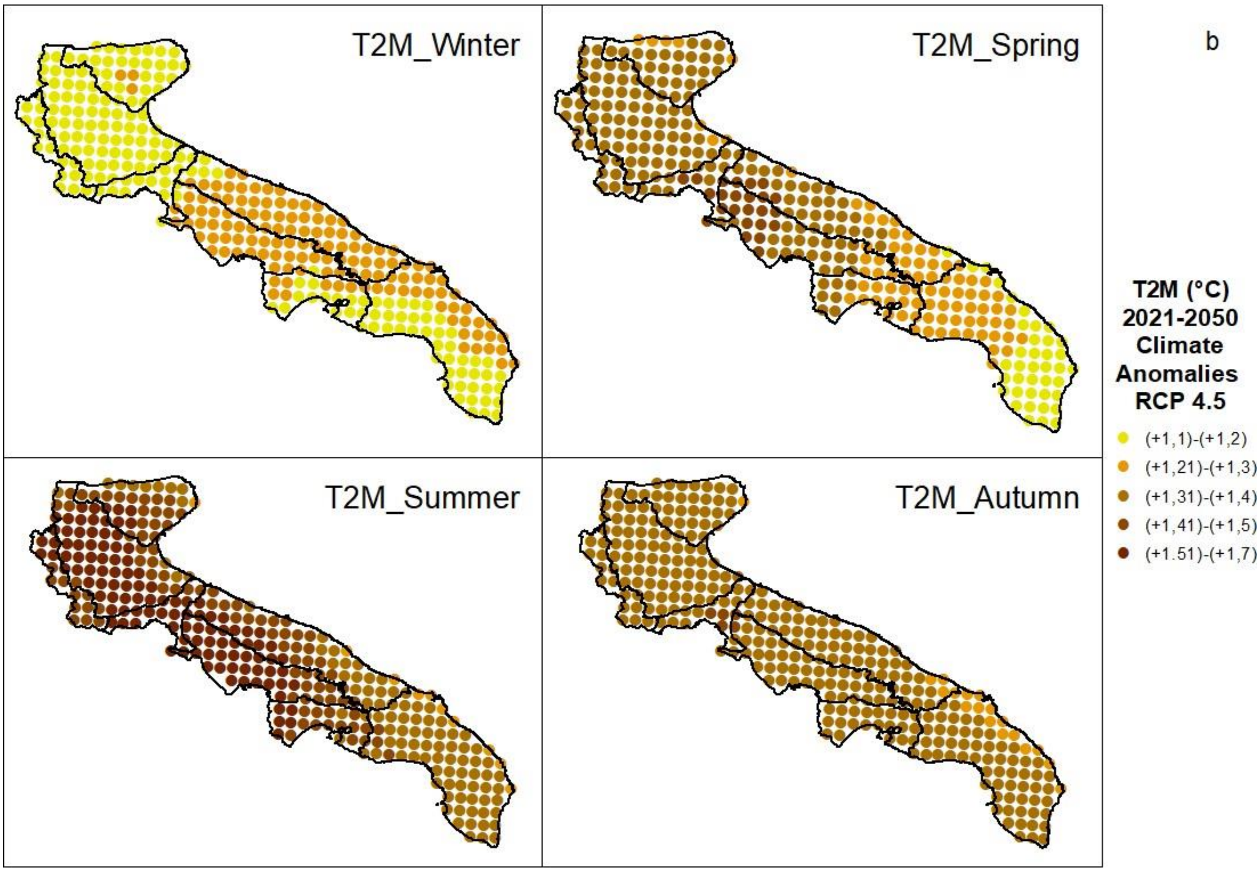


Figure 2.10b. Distribution of anomalies of average seasonal temperature (T2M), calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP4.5.

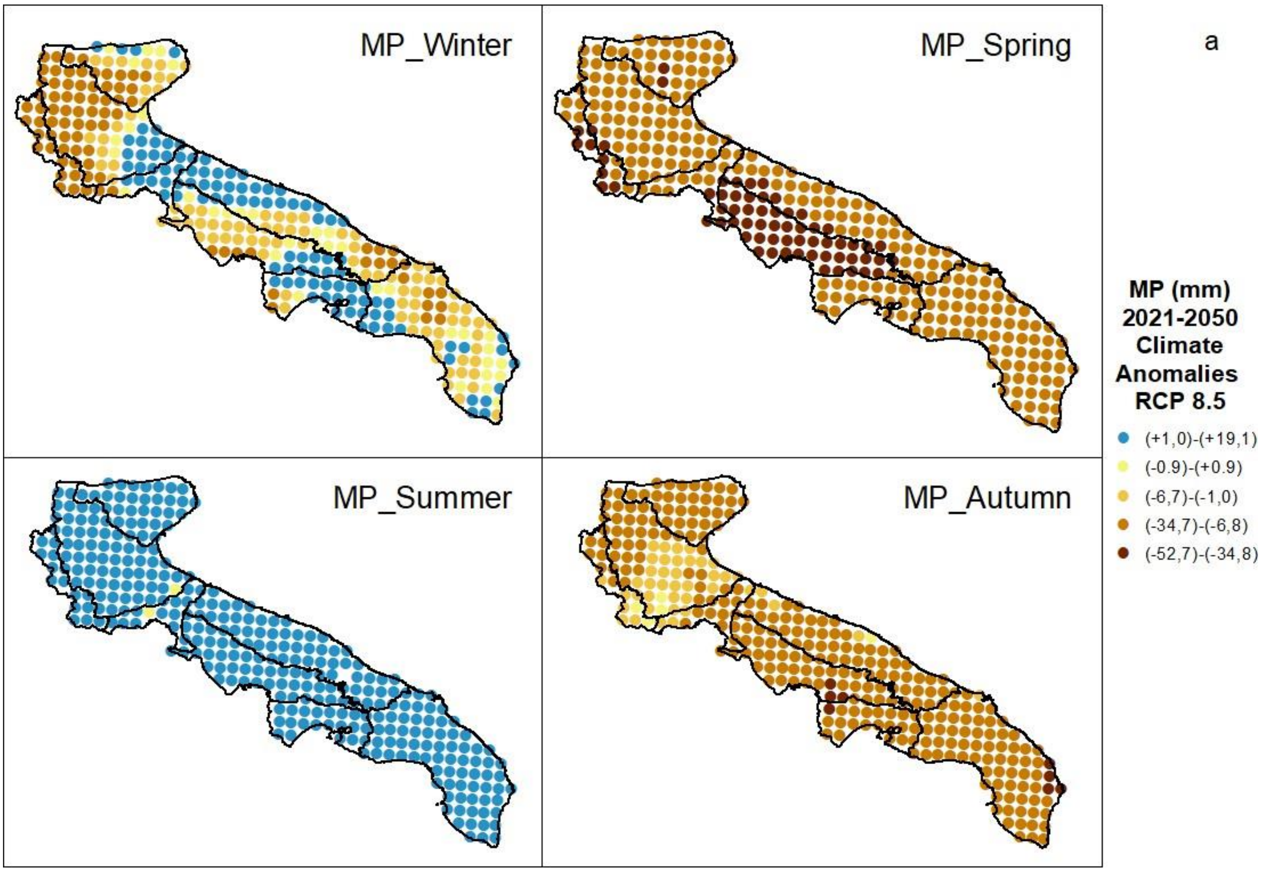


Figure 2.11a. Distribution of anomalies of average seasonal precipitation (MP), calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP8.5.

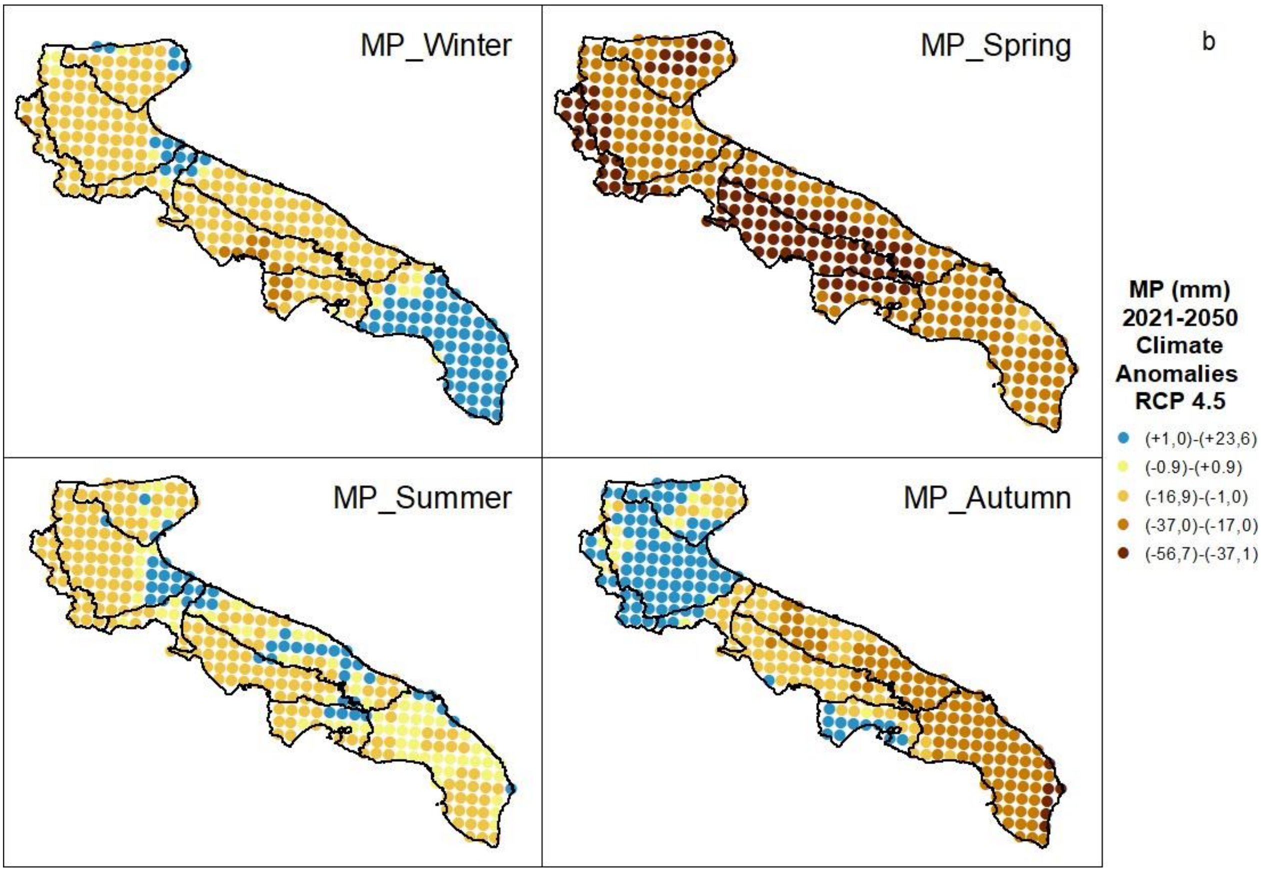


Figure 2.11b. Distribution of anomalies of average seasonal precipitation (MP), calculated on future period 2021-2050 with reference to historical period 1979-2005 for climate scenario RCP4.5.

Figures 2.10a and 2.10b show a general increase in temperatures in each season, for both future scenarios considered (RCP8.5 and RCP4.5).

In the RCP8.5 scenario, each season experiences temperature increases of more than 1.4°C with peaks around 2°C (Figures 2.10a). The winter season experiences the largest average temperature increases. This is followed by spring and autumn with average temperature increases of more than 1.8°C. The summer season records a further increase in average temperatures, with maximum growth values of 1.7°C.

In the RCP4.5 scenario, there are temperature increases of more than 1°C, with maximums of 1.7°C (Figures 2.10b). The summer season records the highest average temperature increases on a territorial level, especially for the Tavoliere, Valle dell'Ofanto, central Adriatic Apulia and the Altopiano delle Murge. In spring and autumn, the expected temperature increases are similar (about 1.46°C). The winter season records temperature increases throughout the region, with peaks of 1.25°C.

For both future scenarios, the projected increase in average temperatures will lead to a gradually milder winter, spring, and autumn climate. In the summer season, average daily temperatures will increase, and these may be matched by higher and more frequent heat peaks (Simolo et al., 2014).

Analysing Figures 2.11a and 2.11b, the seasonal average precipitation anomalies show a general decrease in precipitation, which is more pronounced in the RCP4.5 climate scenario.

The spring season has the largest decrease in average precipitation in both future scenarios. The summer season, however, shows different anomalies. In the RCP8.5 scenario, summer rainfall is expected to increase over the entire territory (Figures 2.11a). The RCP4.5 scenario shows a general decrease in summer precipitation, with the exception of limited areas of the Adriatic coastal strip (Figures 2.11b). The fall season records a decrease in rainfall throughout Apulia for the RCP8.5 scenario and only for south-central Apulia for the RCP4.5 scenario. The winter season shows a decrease in precipitation in the RCP4.5 scenario, except for the Salento peninsula and other limited areas.

For an assessment of the anomalies of the climate indicators calculated for the period 2021-2050, compared to the reporting period 1979-2005, reference can be made to Table 2.4.

Indicator	Average Value		Maximum Value		Minimum Value	
	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5
T2M (°C)	+1.70	+1.36	+1.81	+1.46	+1.55	+1.21
MP (mm)	-38.19	-48.61	-1.40	-0.38	-80.19	-91.92
CDD (days)	+2.04	+3.98	+14.07	+18.53	-10.48	-8.16
R20 (days)	+0.01	-0.35	+1.09	+0.68	-1.06	-1.42
FD (days)	-11.61	-6.33	-1.20	-0.30	-26.03	-18.63
SU95p (days)	+14.63	+13.76	+20.22	17.85	+2.54	+1.64
P95 (mm)	+1.18	-0.03	+4.95	+2.95	-1.57	-3.38
T2M winter (°C)	+1.85	+1.19	+1.94	+1.25	+1.73	1.09
T2M spring (°C)	+1.69	+1.34	+1.82	+1.48	+1.46	+1.13
T2M summer (°C)	+1.55	+1.49	+1.75	+1.69	+1.41	+1.23
T2M autumn (°C)	+1.72	+1.39	+1.86	+1.46	+1.56	+1.26
MP winter (mm)	-2.65	-4.37	+17.20	+23.58	-33.87	-25.12
MP spring (mm)	-27.06	-32.33	-7.13	-13.81	-52.74	-53.66
MP summer (mm)	+8.90	-2.38	+19.11	+7.95	+0.41	-13.39
MP autumn (mm)	-17.38	-9.54	+0.93	+20.36	-43.89	-56.66

Table *2.4.* Average, maximum and minimum annual/seasonal values of climate indicators, *calculated on future period 2021-2050 with reference to historical period 1979-2005 for Apulia Region.*

In conclusion, the results of the climate analysis describe a future climate in Apulia that is generally warmer and less rainy than at present. A decrease in the number of frost days (FD) and a significant increase in the number of summer days (SU95p) are expected. The periods without rain (CDD) will increase their duration while the number of days with heavy rain (R20) will not change significantly. The intensity of rainfall events (P95) may increase throughout the region.

The climate projections presented in this chapter are consistent with the rich body of scientific studies and research produced on the subject of climate change, with a specific focus on the Mediterranean area. Analyses produced by the multitude of global and regional climate models identify the Mediterranean, and thus Apulia, as a region that is especially vulnerable to global climate change (Giorgi & Lionello, 2008; Barkhordarian et al., 2011; Jacobeit at al., 2014; Todaro et al., 2022).

2.4 Current and future climate analysis of sea areas

The analysis of the sea areas surrounding the regional territory aims to qualify them, for the reference period and for the future period, in order to further support the multi-sectoral analysis of the resulting impacts.

Climate data and results on sea areas were taken from the 2022 NCCAP, where two climate indicators were identified to describe the impact of climate change on Italian seas: sea surface temperature (SST) and sea surface height (SSH) (Table 2.5).

Indicator		Atmospheric Variable	Description	Measurement unit
	Sea surface temperature (**SST**)	T	Average sea surface temperature	°C
	Sea surface height (**SSH**)	W	Sea level rise	[m]

Table 2.5. Climate indicators used for the current and future climate analysis of sea areas of Apulia Region

For the evaluation of the current climate condition over marine areas, the National Plan uses marine analyses for the Mediterranean Sea (Simoncelli et al. 2019), produced using services made available by the European CMEMS (Copernicus Marine Environment Monitoring Service). These analyses are obtained by integrating numerical models and assimilating multi-platform observations and represent the state of the art for the characterisation of sea weather conditions.

The data available for the Mediterranean Sea covers the period 1987-2010 and has a horizontal resolution of approximately 7 km.

The sea surface temperature (SST) and sea surface height (SSH) indicator maps for Apulia are shown in Figures 2.12.

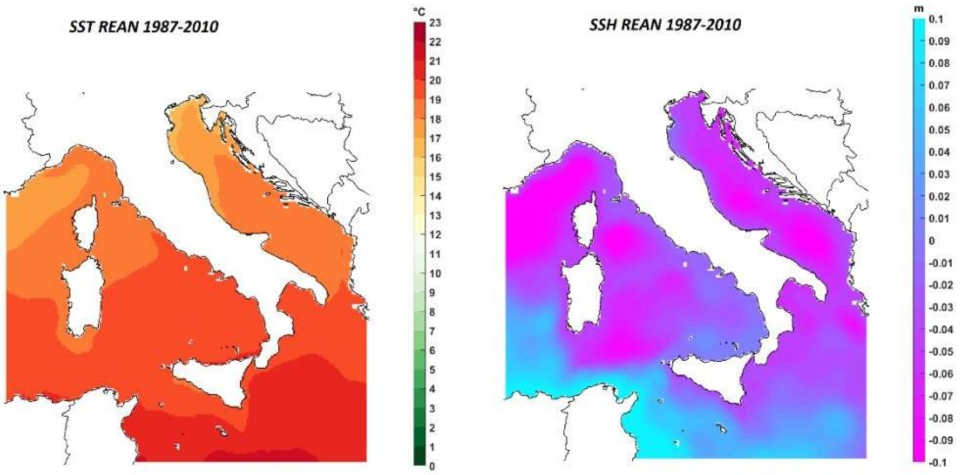


Figure 2.12. Values of SST and SSH indicators on Central Mediterranean Sea obtained from REAN dataset for reference period 1987-2010.

In order to study the expected climate anomalies in temperature and sea surface height, the 2022 PNACC considers climate simulation data for the period 1981-2100 obtained through the NEMO ocean model (Madec, 2008) applied to the Mediterranean Sea (7 km resolution) and forced with atmospheric and hydrological data from the CMCC-CM climate model at 80 km horizontal resolution (Scoccimarro et al., 2011). The model configuration used in these simulations, identified as MEDSEA, was developed by the CMCC Foundation and describes the system evolution for the RCP8.5 climate scenario (Lovato et al., 2013; Galli et al., 2017; Reale et al., 2022). As already mentioned, the RCP8.5 scenario is the most precautionary condition as it describes the climate evolution for a 'business as usual' emissions scenario.

Anomalies on an annual basis for sea surface temperature (SST) and sea surface height (SSH), respectively, were calculated using MEDSEA climate data for the historical period (1981-2010) with reference to the future scenario (2036-2065), averaged within the coastal areas within 12 nautical miles for the marine sub-units bordering Apulia.

The results refer to the Italian seas divided into four macro-regions on the basis of the Marine Strategy Framework Directive (MSFD 2008/56/EC acknowledged in Italy by Legislative Decree 190/2010): Western Mediterranean Sea, Adriatic Sea, Ionian Sea and Central Mediterranean Sea, macro-regions further divided into eight sub-units (Figures 2.13).

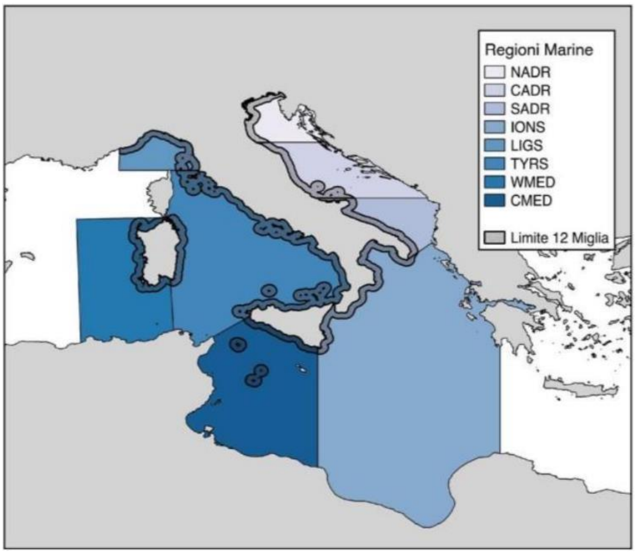


Figure 2.13. Italian seas division in specific marine sub-regions (Fratianni et al. 201633). The shaded area shows the limit of 12 miles from the coastline. Marine regions are identified using the following acronyms: NADR: Northern Adriatic Sea; CADS: Central Adriatic Sea; SADR: Southern Adriatic Sea; IONS: Ionian Sea and Central Mediterranean Sea; LIGS: Ligurian Sea: TYRS: Tyrrhenian Sea; WMED: Western Mediterranean Sea; CMED: Central Mediterranean Sea.

Table 2.6 shows the yearly climate anomaly values for sea surface temperature (SST) and sea surface height (SSH) for the marine sub-units bordering Apulia: Southern Adriatic Sea (SADR) and Ionian Sea (IONS).

Area marina	SST [°C]	SSH [cm]
SADR	+2.24	+16
IONS	+2.03	+17

Table 2.6. Anomalies in average sea surface temperature (SST) and sea level (SSH), calculated as a difference between the reference periods 2036-2065 and 1981-2010 using MEDSEA dataset. Source: PNACC 2022.

The climate anomaly of surface temperature shows, in all sea areas bordering the Apulian coast, an increase in temperature of more than 2°C compared to the 1981-2010 reference period (18-20°C). The 2022 PNACC shows that the temperature increase will be almost constant throughout the year while keeping the seasonality of each zone unchanged.

As with sea surface temperature, sea surface height will also rise during the period 2036-2065 for the RCP8.5 scenario in all Apulian marine areas. An average sea level rise of 16 cm in the Adriatic Sea and 17 cm in the Ionian Sea is estimated.

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3. Analysis of climate change impacts in Apulia, sectoral vulnerabilities and adaptation actions

3.1 Impacts and adaptation actions for aquaculture

3.1.1 Analysis of the current scenario for the sector

The marine environment offers a wide range of benefits spanning all categories of ecosystem services: support, provision, regulation and cultural services. Due to intense human activities, these ecosystem services are exposed to various drivers of change, which contribute to their degradation and loss. Climate change, caused by largely anthropogenic global warming, is considered one of the main drivers of change that can negatively impact the productivity of ecosystems and food production systems on the planet and in the European Union (EU). Aquaculture is no exception, and it is vital that planners and practitioners are prepared to adapt to changing conditions in order to maintain an environmentally and socio-economically sustainable aquaculture.

Aquaculture is a very important economic sector of food production that has been experiencing rapid growth in recent years, both globally and in the European Union. It grew by 11 percent in volume and 40 percent in value over the 2010-2019 period, and accounts for approximately 30 percent of fish production. Aquaculture includes the production of sea and freshwater fish as well as molluscs, from various farming systems: closed or open, extensive or intensive, on land, in lakes, ponds, near the coast or offshore. Starting out as a small-scale, artisanal activity, aquaculture has become a high-tech industry involving fully integrated commercial activities (European Commission, 2009).

In 2018, world aquaculture production, including aquatic plants, amounted to approximately 114 million tonnes, with an estimated value of USD 263 billion, while the Union's aquaculture production stands at around 1.1 % of world production. In 2017, total EU aquaculture production reached 1.37 million tons and 5.06 billion euros (Figures 3.1.1.A).

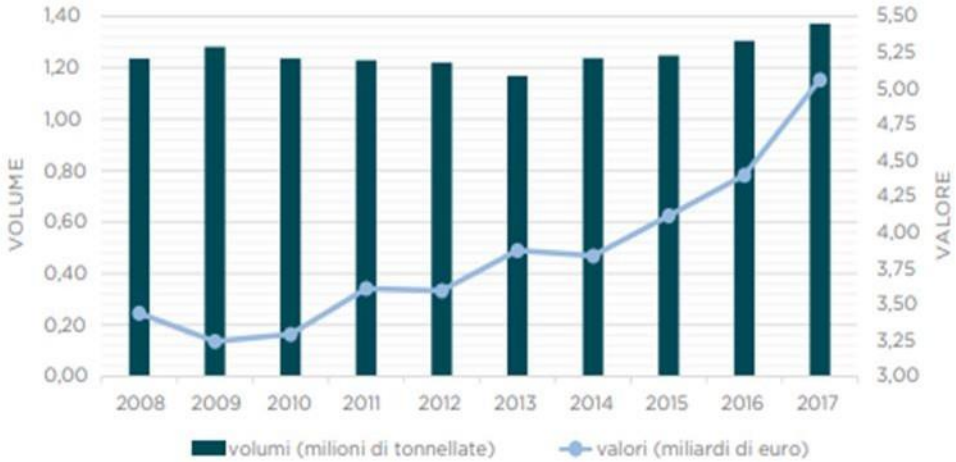

Figure 3.1.1.A. Aquaculture production trend in EU. Source: EUMOFA, 2019.

Volume (million tons) x value (billion euros)

Currently, European fisheries and aquaculture productions meet 20% and 10% of domestic demand for fish and molluscs respectively, while almost 70% of the seafood consumed in Europe comes from third countries (EUMOFA, 2018), generating an annual trade deficit of EUR 21 billion in 2019 (European Commission, Directorate-General for Maritime Affairs and Fisheries, The EU Fish Market: 2020 Edition, Publications Office, 2021). European aquaculture directly employs more than 74,000 people in over 12,000 enterprises (The EU Aquaculture Sector - Economic Report 2020, (STECF-20-12) EUR 28359 EN, Publications Office, 2021). However, nearly 80 percent of all enterprises in the EU are micro-enterprises with fewer than ten employees. Almost 70% of the EU's aquaculture production is concentrated in four Member States (Spain, France, Italy and Greece) and the majority of production is mussels, trout, oysters, perch, carp and clams. Norway holds the top spot in farmed salmon production (FAO, 2016). The positive trend in the value of aquaculture over the last decade is due to increased production of higher value species (e.g., salmon, bass), while the volume growth trend is significantly lower than the global trend.

Climate change, caused by largely anthropogenic global warming, is already displaying its potential to challenge existing food production systems in the EU. Aquaculture is particularly sensitive to extreme weather events in river and coastal areas that are occurring with increasing frequency due to global warming, including droughts, floods, storms and coastal storms, which cause severe damage to plants and cultivated species. Rising electricity and gas costs will also burden the entire aquaculture industry in Europe and cause an increase in production costs coupled with commercial uncertainty due to the COVID-19 pandemic crisis and ongoing war-related events. In fact, the demand for aquaculture products in the EU may increase in the near future, but many companies are finding it difficult to maintain their market shares, both nationally and abroad.

At the European level, in addition to the European Climate Law of 2021, a number of policies and directives address climate change within a maritime context, including the Water Framework Directive (WFD, 2000/60/EC), the Marine Strategy Framework Directive (MSFD, 2008/56/EC) and more specifically for the aquaculture sector, the new EU Strategic Guidelines (2021) for a more sustainable and competitive EU aquaculture include considerable detail on 'Climate Change Adaptation and Mitigation'. Other EU directives, such as Marine Spatial Planning (MSP, 2014/89/EU), also recognise the direct link between sustainable aquaculture development and climate change impacts.

In 2021, the European Commission presented the new Adaptation Strategy (COM (2021) of 25 February 2021, Forging a Climate Resilient Europe - The New EU Strategy on Adapting to Climate Change), which replaces the previous Strategy of 2013. The new Strategy, announced in the European Green Deal, aims to achieve Europe's transformation into a climate resilient Union by 2050 and is based on four priorities: smarter, more systemic and integrated adaptation, faster, and intensified international action.

The goals outlined in the European Strategy are reinforced by the so-called European Climate Law (Reg. (EU) 2021/1119 of June 30, 2021) which, by incorporating the Paris Agreement and the United Nations 2030 Agenda into EU law, requires member states to adopt and implement national adaptation strategies and plans, taking into account the EU Adaptation Strategy (Art. 5, par. 9 of EU Reg. 2021/1119).

In addition, the EU has supported a series of innovative studies to investigate the potential impact of climate change on European aquaculture and initiate the development of guidelines and tools for its adaptation and mitigation. The HORIZON 2020 program has funded a number of key projects, including the CERES project and the ClimeFish project. Together they have produced comprehensive case studies for the major fish, molluscs and algae species in aquaculture across Europe and produced guidance documents and tools to help decision-makers and operators.

The Ministry of Ecological Transition (now the Ministry of the Environment and Energy Security - MASE) has incorporated the guidelines set forth in the aforementioned acts of international and EU sources and, consistent with these, as well as with the provisions of the National Strategy on Adaptation to Climate Change (SNAC), has undertaken significant initiatives on the subject of adaptation. These have included, in particular, both the launch of the National Platform on Adaptation (http://climadat.isprambiente.it) and the continuation of the efforts undertaken since 2017 to achieve the adoption of a National Plan on Adaptation.

In October 2022, the Ministry of Ecological Transition (now Ministry of the Environment and Energy Security - MASE), in collaboration with the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), published the National Platform on Adaptation to Climate Change (http://climadat.isprambiente.it). This portal aims to inform and raise awareness among citizens and stakeholders on the issue of adaptation and to make available data and tools to support the public administration in decision-making processes. The Platform will be periodically updated and enhanced with data and information from various sources.

After the extreme weather events, with landslides and floods, that occurred in Ischia, the National Climate Change Adaptation Plan (PNACC) was approved in December 2022, replacing the 2018 National Strategy on Adaptation to Climate Change (SNACC). **The objective of the 2022 PNAC is to establish a national policy framework** to carry out actions to minimise **the risks resulting from climate change**, to improve the adaptive capacity of natural, social and economic systems, and to take advantage of any opportunities that may arise from new climatic conditions (InSic Editorial). The operability of the Plan involves **the planning and implementation of adaptation actions in different sectors** by defining priorities, roles, responsibilities and sources/instruments of adaptation funding and, finally, the removal of both barriers to adaptation constituted by the lack of access to feasible solutions, and regulatory/procedural barriers. The results of this activity will converge into sectoral or cross-sectoral plans, in which the interventions to be implemented will be outlined (InSic Drafting).

The Aquaculture Strategic Plan for (PSA) in Italy (MIPAAF 2015) plans a number of actions for the productive and economic development of aquaculture and for sustainable, low-impact growth. In the document, there are no measures in place to tackle the impacts of climate change on aquaculture and expanding knowledge is a top priority. The 2014-2020 PSA includes a number of actions aimed at acquiring knowledge and developing tools to assess impacts and risks for the sector, and to plan and implement mitigation and adaptation actions.

EU Regulation No. 508/2014 concerning the European Maritime and Fisheries Fund provides financial support for the implementation of certain actions and investments for aquaculture adaptation to climate change.

The new National Strategic Plan for Italian Aquaculture 2021-2027 (PNSA-Italy) aims to provide guidance and support to regional administrations, stakeholders and others involved in Italian aquaculture activities, in order to address old and new challenges for the sector in future years. The PNSA-Italy was born as a result of a dialogue with stakeholders and regional administrations in the context of the Aquaculture Platform - ITAQUA, a fundamental tool that the Directorate General for Maritime Fisheries and Aquaculture of the MIPAAF adopted in 2017.

The new PNSA-Italy follows the 'Strategic Guidelines for a more sustainable and competitive EU aquaculture for the period 2021 - 2030', to which the Italian administration contributed during negotiations with the European Commission and EU Member States. The document was drafted from the actions contained in the previous 2014-2020 PSA, analysing the positive results achieved and building on the lessons learned during the previous programming.

Also in the new PNSA-Italy within Macro Obiettivo 3 - Promuovere la competitività dell'acquacoltura[1], strategic line 3, (S 3.1 - Investimenti per migliorare la competitività, la sostenibilità, la redditività e la resilienza delle imprese acquicole[2]), of extreme relevance for the whole PNSA, is mainly aimed at fostering investments with a view to sustainability, primarily to improve environmental performance in the aquaculture sector, including through the mitigation of environmental impacts, the enhancement of environmental services, the conservation of biodiversity and the mitigation of climate change.

In Italy, aquaculture is a significant sector in national fish production and accounts for about half of the production volume. Closely connected to inland, transitional and marine environments and ecosystems, it is considered by the European Environment Agency, the Intergovernmental Panel on Climate Change and the FAO to be among the socio-economic sectors that are most vulnerable to climate change (EEA 2012c; Pörtner et al. 2014; Brugére & De Young 2015).

[1] Macro Objective 3 - Promoting aquaculture's competitiveness.

[2] Investments to improve the competitiveness, sustainability, profitability and resilience of aquaculture enterprises.

3.1.1.A. Analysis of the aquaculture sector in Apulia

Italian aquaculture is an important sector of the national agribusiness and has grown to be a highly diversified activity because of the high environmental diversity present in Italy. In 2017, around 150,000 tonnes of fresh fish, molluscs and crustaceans worth more than half a billion euro were produced in Italy. Aquaculture products account for 44% of the total volume of the national fishery sector and over 35% of its value (Figures 3.1.1.a.1). Aquaculture in Italy is very diverse in terms of species, rearing environments and production techniques. More than 30 species of fish, molluscs, crustaceans and algae are bred in around 750 production facilities, located in coastal marine areas, transitional environments and fresh waters. Most of the production, however, involves five main species: rainbow trout, in fresh waters, sea bass, sea bream, mussels and clams, in brackish and marine waters (ISPRA - MiPAAF, 2020) (Figures 3.1.1.a.2). The historical output series shows a strong decrease in production capacity for fish farming after 2001 due to a reduction in the number of plants and a significant decrease in traditional valley production, not compensated by other innovative production activities. In the case of shellfish farming, fluctuations are generally due to the close relationship of certain production systems with the environmental conditions of the waters used for shellfish life, which are often not optimal. Despite initially showing very high growth potential, over the last decade, Italian aquaculture, following the European trend, has been unable to fulfil that vicarious function to fisheries for the supply of fish products. Regionally, Veneto and Emilia-Romagna top the list in terms of the number of plants and production. Friuli-Venezia Giulia, Apulia and Sardinia together host 69.3% of aquaculture facilities in their territories and account for 74.3% of national production. In particular, Apulia, with its approximately 1,000 kilometres of coastline, plays a prominent role in the context of Italian mariculture. Indeed, the latest Figures show a volume production of 12,000 tonnes worth more than EUR 28 million in 2013, with a total of 64 plants. A total of 32 farms dedicated to fish farming operate along the Apulian coast, including 23 in the province of Foggia, 1 in the province of Bari, 3 in the province of Brindisi, 4 in the province of Taranto, and 1 in the province of Lecce. With regard to active offshore plants (9 plants surveyed, see Figures 3.1.1.a.3), most are located in the provinces of Foggia (4) and Taranto (3), with only one offshore plant for the provinces of BAT and Lecce respectively. The main fish species farmed in Apulia are sea bass and gilthead seabream, as well as a small production of meagre and, exceptionally, American meagre. There are two hatcheries for bass and gilthead seabream that are also very active internationally.

Shellfish farming in Apulia is carried out in Taranto and along the Gargano coast. In the Gargano there are a total of 36 farms, 27 of which are located along the northern coastal area of the Gargano, including the Varano lagoon, and 9 in the waters of the Gulf of Manfredonia (Figures 3.1.a.4). Of the 36 farms, 23 practice breeding in salty waters (64%) (14 along the northern side of the Gargano and 9 in the waters of the Gulf of Manfredonia), while the remaining 13 farms practice breeding in the brackish waters of the Varano lagoon.

The species most commonly farmed along the northern coasts of North Gargano, in the Varano lagoon and the Gulf of Manfredonia, are *Mytilus galloprovincialis*, *Crassostrea gigas* and *Ruditapes philippinarum.*

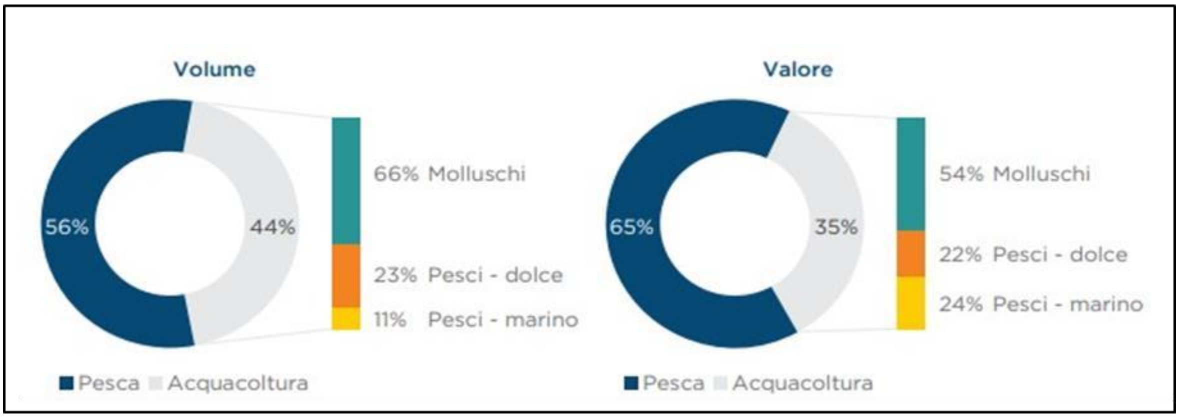

Figure 3.1.1.a.1 – Contribution in percentage of fishing and aquaculture in volume and value in reference to the Italian fishery sector. Source: ISPRA, 2019. Data: Molluscs, freshwater fish; Salt water fish.

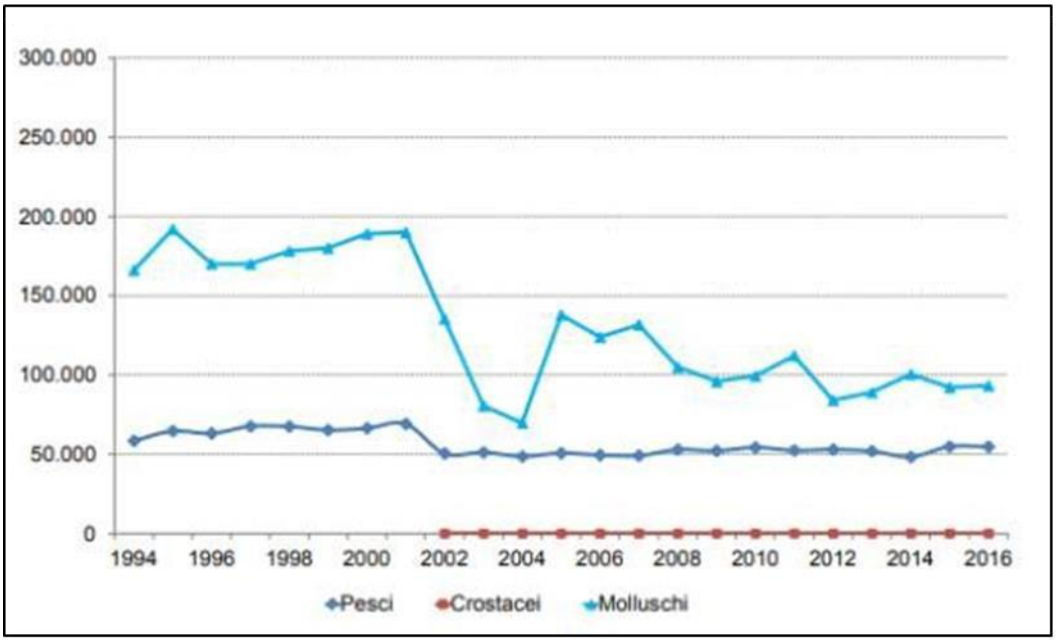

Figure 3.1.1.a.2 – Annual production in aquaculture of Fish, Molluscs and Crustacean. Source: Developed by ISPRA, 2019 based on data provided by MiPAAF-ICRAM (1994-2001), IDROCONSULT (2002-2006), UNIMAR (2007-2014), MiPAAF-GRAIA-API-AMA (2015-2016).

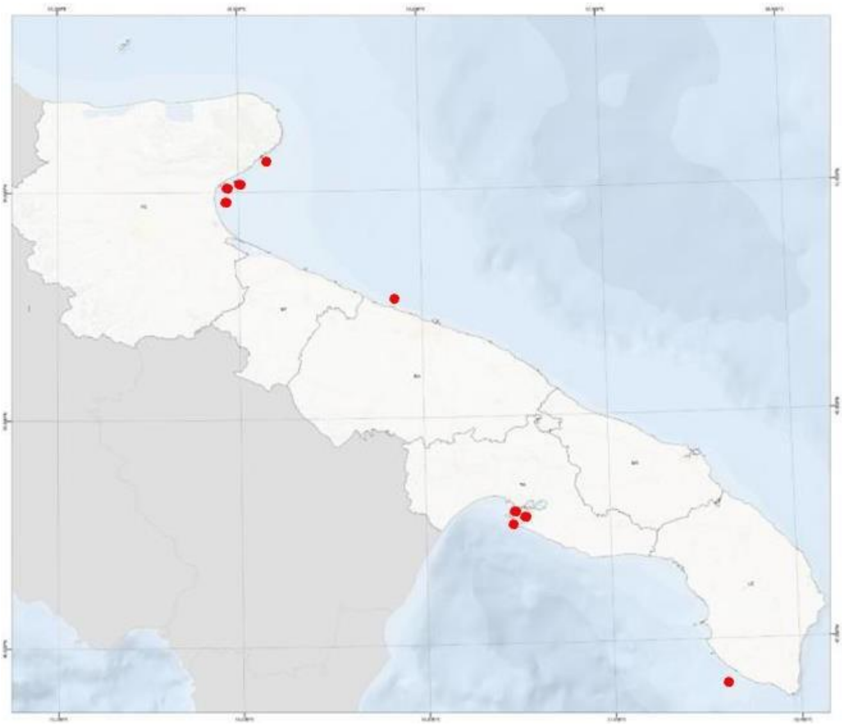

Figure 3.1.1.a.3 – Map of fish farming plants active ashore (●) in Apulia Region.

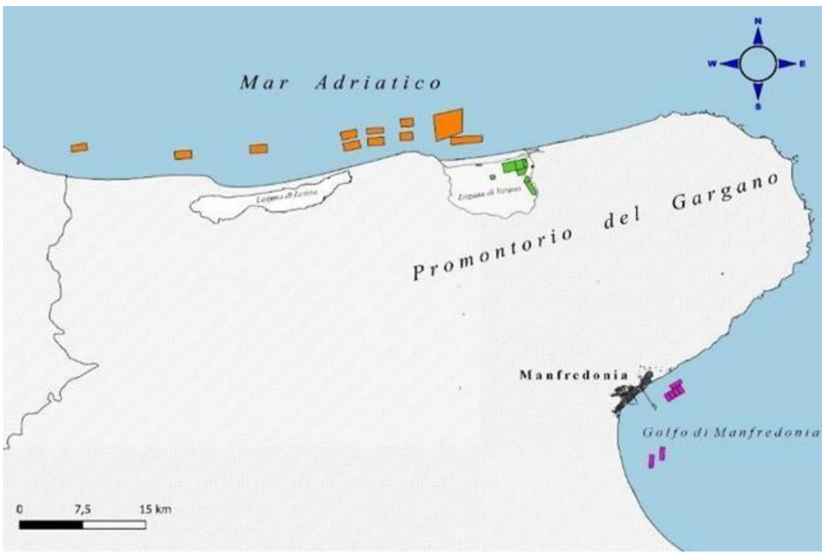

Figure 3.1.1.a.4 – Map of official shellfish farming plants active on the Gargano shoreline of Northern Apulia Region

3.1.2 Analysis of expected impacts

The European Commission recognised the specific role of aquaculture in the reform of the Common Fisheries Policy and affirmed the need to develop a strategy for the sustainable development of this sector. In this context, the sustainability of aquaculture activities depends on the maintenance and preservation of environmental systems and functions that, in turn, contribute directly or indirectly to the well-being of communities and ensure the continuity of production activities. By introducing a high density of additional life into coastal marine waters, mariculture affects the surrounding environment in varied and complex ways, often negatively. The magnitude of these effects is heavily influenced by operational characteristics, such as the species being reared, the stocking density and the feeding strategy. For example, the filtering activity of farmed bivalves is a key driver of environmental benefits, but on the other hand, farmed bivalves compete with wild populations for suspended food and consume the planktonic larvae of many species of fish and invertebrates. These processes are difficult to assess as they are complex and context-dependent (state of wild populations, farming methods) and to minimise the costs of such externalities, the cultivated biomass must remain within the local load capacity.

Effluents from fish farms contain uneaten feed, metabolic excretions, faeces, i.e., solid organic waste and dissolved organic and inorganic nutrients composed largely of nitrogen and phosphorous. If the flow of these compounds released into the environment exceeds the natural assimilation capacity of a water body, ecological alterations may occur in both the water column and the sediment, causing, as an extreme consequence, eutrophication phenomena, reduced dissolved oxygen, increased turbidity and alterations of macro-benthic habitats in the sediment. The extent of the ecological impact is dependent mainly on the physical and oceanographic conditions of the site, the water temperature, the concentration of dissolved oxygen, but also on the size of the plants, the biomass on the farm and the management practices employed. In the case of offshore cage installations, the study of the hydrodynamic characteristics of the site can yield important information on the distribution of organic effluent on the sediment.

Physical factors such as water temperature, currents, sunlight, nutrient availability, etc., have a direct effect on the growth of aquaculture species, especially for autotrophic species and filter feeders as they depend on their surroundings for energy supply. Aquaculture production is therefore affected by a combination of external climatic variables, including droughts, floods, global warming, ocean acidification, rainfall variation, salinity and sea-level rise (De Silva et al., 2009), making it highly sensitive to climate change. Changes in thermal regimes, rainfall and their effects on dissolved oxygen concentration and salinity can have direct effects on the reproduction, growth and survival of farmed species. Similarly, for species where breeding depends on the availability of wild-collected seed and juveniles, changes in the habitats on which adults depend may reduce the availability of seed material, with indirect effects on production cycles. On a European scale, the northern European countries ae those where the most significant impacts are expected, both because of the greater influence of climate change in the Atlantic region compared to the Mediterranean region, and because of the great economic importance of aquaculture in these countries.

On a Mediterranean scale, the potential impacts on aquaculture are different between countries north and south of the Mediterranean (Rosa et al., 2012). In Italy, although there is still no specific knowledge and evidence on the vulnerability of aquaculture activities related to climate change, concern has been growing in recent years in particular for the effects that climate change may have on shellfish production (Viaroli et al., 2007; Melaku Canu et al., 2010). Current environmental strategies and regulations at EU and national level in the areas of climate change adaptation, maritime spatial planning, green transition and blue economy promote the development of aquaculture in the Mediterranean area and a thorough assessment of the effects that climate change may bring on the development of the sector. Extreme weather conditions, which are becoming more intense and more frequent, cause major effects such as, for example, rising sea levels that can have an effect on aquaculture in coastal areas. Other changes due to climate change, which may affect livestock farming, include the increase in sea and atmospheric temperatures due to global warming, leading to a decrease in dissolved oxygen concentration due to lower oxygen solubility in warmer waters, and the rise in atmospheric CO_2, which causes ocean acidification (Greenwood et al., 2010). This condition of increased vulnerability of aquaculture production is already a dramatic situation in Apulia as well. The Apulian shellfish industry is suffering from the heatwaves that are now occurring more frequently and especially in the summer period, i.e. just when production is ready for the market. These sudden changes in temperature cause major losses of produce and, consequently, revenue, thus jeopardising the survival of the entire production sector. Since such sudden temperature increases cannot be prevented, the solution must be sought in a system to reduce product losses. By using satellite tracking technology, *in-situ* monitoring and numerical modelling, and integrating the results of the forecasts into an 'early warning' information system, shellfish farmers can be warned early enough to give them the chance to secure production, for example, by moving them to another body of water.

In general, the main climate variations that will affect the Mediterranean region with possible implications for aquaculture are:

- increase in water temperature (expected to be about + 2°C by the end of the century);
- salinity increase (0.5 ppt by the end of the century, more in the Adriatic);
- Acidification of the sea (0.3-0.4 pH units by the end of the century);
- sea level rise (30-60 cm by the end of the century);
- increased frequency of extreme weather-climate events (heat waves, drought episodes, heavy rainfall, floods, coastal storms);
- reduction in average annual precipitation and river flows (and associated reduction in primary and secondary productivity along coastal areas near the mouths of major rivers);
- stress on water resources.

In addition, climate variations could lead to major biophysical effects of change on species, particularly for:

- exceeding the thermal tolerance of bred species;
- hypoxic water conditions (stratification);
- phenological changes of species (early maturation, early reproduction, early appearance of larval forms etc.);
- calcification problems of organisms (mollusc shell and developmental problems);
- development of harmful organisms *(*algalblooms, jellyfish invasions etc.);
- increased risk of disease spread and increased virulence of pathogens;
- Introduction of new pathogens;
- spread of invasive species;
- coastline retreat and increased erosion (flooding/seawater etc.);
- reduction in water quality and availability (especially in the South and the islands).

According to the relevant literature there is evidence of potential impacts of climate change on aquaculture (Figures 3.1.2.A modified from De Silva, 2012):

- reduced growth and survival of species;
- occurrences of widespread die-offs;
- increased susceptibility to disease;
- new diseases;
- health risk from algal biotoxins;
- alteration of the migratory phases and reproductive cycle of fish species;
- reduction of natural and seed recruitment for the start of production cycles;
- infrastructure damage and loss of raised lots;
- reduction of suitable sites for breeding;
- reduced availability of fishmeal and fish oil for feed, and higher prices;
- reduced productivity.

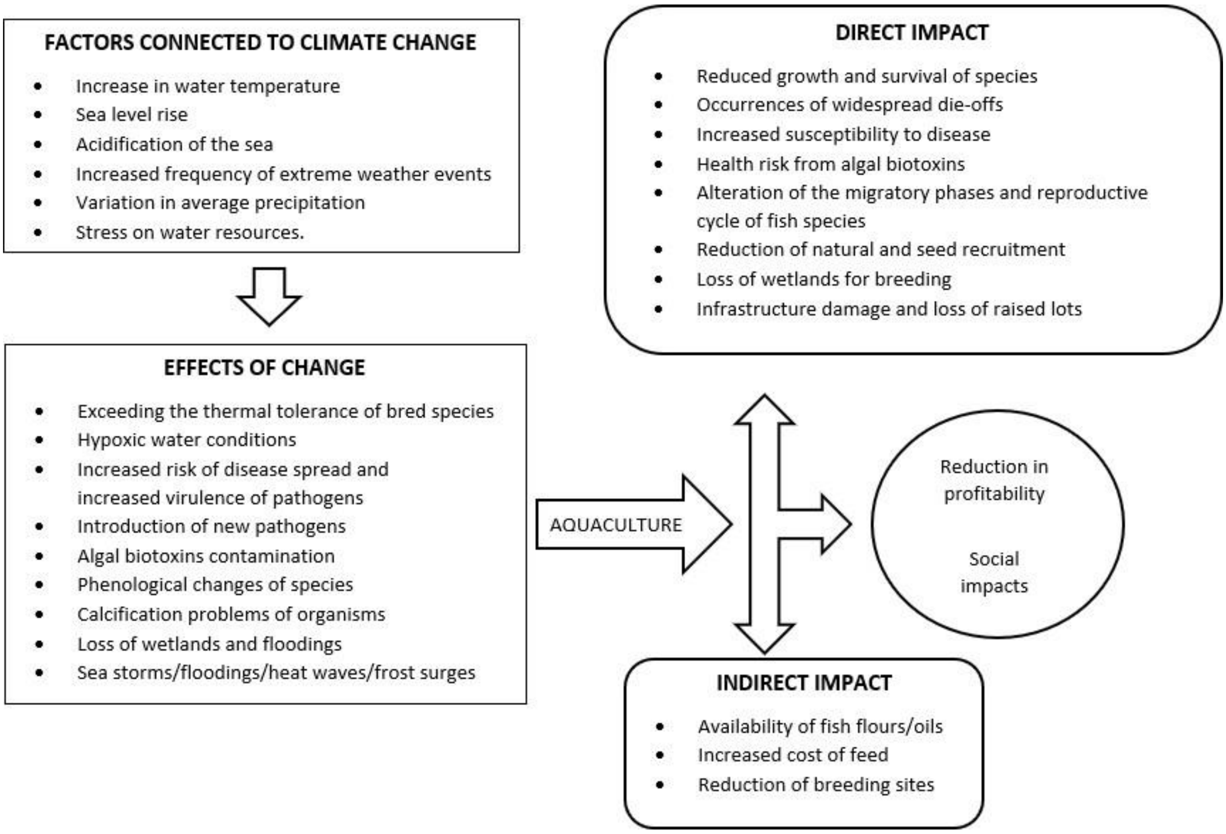

Figure 3.1.2.A – Schematic representation of the main potential impacts of climate change on aquaculture (modified from De Silva, 2012)

Therefore, the impacts of climate change on Italian shellfish farming may include several aspects, such as:

- the reduction in the performance of bred species;
- changes in the reproductive cycle of species, resulting in reduced natural recruitment and seed availability;
- the conditions of stress, disease outbreaks, mortality events due to the changed and/or unfavourable environmental conditions;
- incidents of contamination related to water quality;
- infrastructure damage and the loss of biological material related to extreme weather-sea events.

For marine fish farming, particularly when located in offshore areas, the greatest impact will be driven by the increased frequency of extreme marine weather events.

Although the current knowledge about the impacts of climate change on aquaculture activities allows certain predictions and assessments to be made about the possible effects on the physiology of bred species, the availability of suitable breeding sites, the risks to animal and public health and the economic sustainability of the industry, implementing knowledge about the vulnerability of aquaculture to climate change is a priority.

There is a need to acquire more detailed knowledge of the effects of climate change on the various bred species (biology, ecology, genetics, and health), via experimental tests, the development of forecasting models and specific indicators; on the possibility of selecting species/strains tolerant to climate change-induced conditions; and to develop methods (risk analysis) for analysing the vulnerability of the various production systems in the country. Additionally, monitoring systems also need to be implemented through the use of satellite data and data collection systems for the physical-chemical and biological characteristics of water bodies. Finally, vocational training for the aquaculture sector is of particular importance in order to attract young people and enable fishermen to retrain, helping to create jobs in coastal and island regions that are traditionally more dependent on fishing activities.

Figures 3.1.2.B shows the geographically-based analysis of climate change vulnerability of production systems in aquaculture (Castellari et al., 2014).

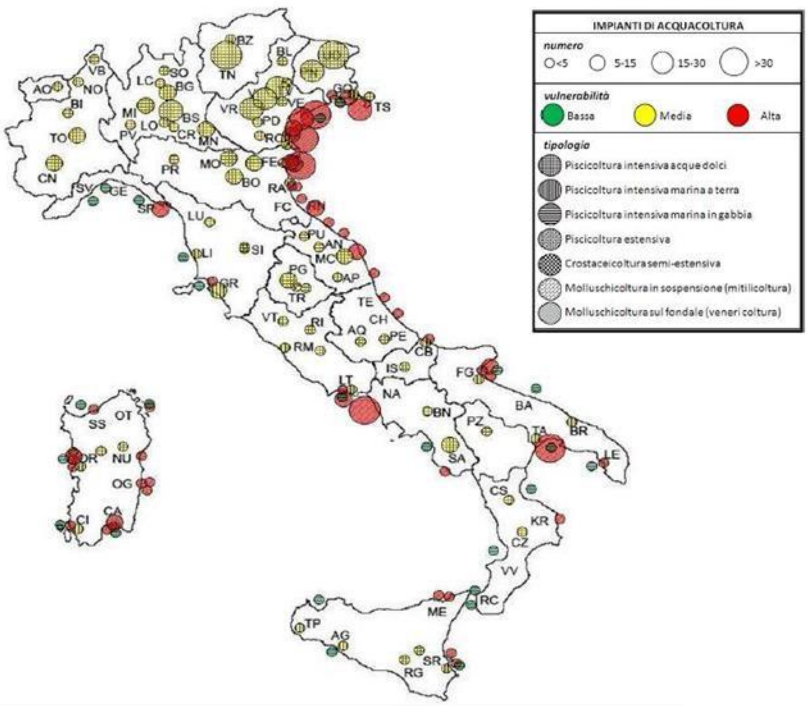

Figure 3.1.2.B – Vulnerability of Italian aquaculture production systems to climate change (from Castellari et al., 2014)

A - Increase in surface water temperature

Thermal tolerance of species

Temperature has a direct influence on the physiology of aquatic organisms as heterothermic animals. Increased temperature stimulates the metabolism, energy consumption and growth of organisms, up to the thermal tolerance limit of species. Thermal limits are determined by the limited capacity of the cardiovascular and respiratory systems to meet the oxygen demand of tissues, which cease their specific activities and functions under anaerobic conditions (Pörtner and Farrell, 2008). Below the thermal tolerance limit of the species, raising the water temperature can have positive effects on aquaculture in terms of increased animal growth and shorter rearing cycles (King and Pankhurst, 2007). However, the temperature window, between the optimal and criticaltemperature at which undesirable effects on growth, reproductive functions and disease susceptibility begin to appear, is very narrow (Battaglene et al., 2008). The influence of temperature on species reproduction has important implications for aquaculture. An inhibitory effect on gametogenesis and gonadal maturation in broodstock has been observed in farmed Atlantic salmon. The regulation of water temperature by means of appropriate technologies or, alternatively, the application of hormone therapies that are able to stimulate normal endocrine functions are possible measures to remedy this problem (Pankhurst and King, 2010).

Reduction of oxygen concentration in water is another problem resulting from rising temperature. Excessively high average temperatures or summer heat waves can lead to zones of anoxia, termed dead-zones for sessile species, on shallow areas. This phenomenon can have undesirable effects on the breeding of molluscs, particularly clams, mussels and oysters, for which a survival time reduced by 74% and an average lethal oxygen concentration that increases with increasing temperature has been observed under hypoxic conditions (Vaquer-Sunyer and Duarte, 2011).

Eutrophication and toxic algal blooms.

Rising temperatures associated with water eutrophication can result in algal blooms that produce biotoxins, which are dangerous to aquatic species and humans (Hinder et al., 2012). The effects produced by blooms differ among species. Some species grow at concentrations that reduce the concentration of oxygen and create hypoxic conditions that can cause fish, molluscs and other invertebrates to die, with negative consequences for farmed stocks. Other species produce potent toxins that accumulate in the food chain and can cause various effects in secondary consumers, filter-feeding animals such as bivalves and humans through consumption of contaminated shellfish. Over the past decade, intoxication phenomena have been reported in several countries along the Mediterranean basin. In Italy, the National Reference Laboratory for Marine Biotoxins reports cases of intoxication in Friuli and Emilia-Romagna, and more frequent cases in Sardinia caused by Dinoficee.

Incidence and spread of diseases

Climate change will have a major impact on the spread of pests and pathogens in aquatic ecosystems primarily as a result of increased temperature and the frequency of extreme weather events (heavy rainfall, floods, heat waves, droughts), which in turn cause environmental changes (Marcogliese, 2008; Levinton et al., 2011). The distribution of parasites and pathogens will be influenced directly by rising temperatures, and indirectly through an increase in the range of host species and their abundance. The transmission and virulence of pathogens and parasites may also increase because of the rise in temperature. Thermal stress in itself will be able to act as a stressor for aquatic organisms and cause a reduction in immune defenses. It is therefore expected that variations in climatic factors may lead to an increased epidemiological risk in aquaculture linked to the emergence and spread of new fish diseases with a strong economic impact, and to changes in host-pathogen interactions, with an increase in the prevalence of certain infectious/infestive diseases of fish and molluscs, potentially transmissible also to humans (Ghittino, 2011).

Molluscs, especially during the early stages of development, are susceptible to bacterial diseases such as vibriosis. Pathogens of the genus *Vibrio sp.* are ubiquitous in marine waters and their growth is dependent on water temperature.

Phenological changes

Rising temperatures, particularly minimum temperatures, have a direct effect on the phenology of species, altering the timing of the events that mark the life cycle of species throughout the year. The temperature-mediated phenological changes described in the literature for teleost fish include: earlier spawning, early appearance of larval forms, changes in migratory behaviour, higher energy investment for spawning, early maturation, altered growth and reduced lifespan (Franco et al., 2003; Sims et al., 2004). Changes in temperature could therefore have major biological effects and cause a mismatch between reproductive events and trophic availability for the growth of larvae and juveniles, with effects on recruitment and population status.

B - Sea level rise

Rising sea levels will result in the risk of flooding along the coastal strip with loss of wetlands, at river mouths and lowlands. According to a NASA-GISS study, approximately 4,500 square kilometresof coastal areas and plains distributed mainly in the southern Adriatic and Ionian Sea (62.6%), the northern Adriatic (25.4%), the western and southern part of Sardinia (6.6%), and the middle Adriatic and Tyrrhenian Sea (5.4%) would be at risk of flooding. Another problem is the infiltration of salt water into coastal freshwater aquifers with an impact on freshwater availability and quality, and the transformation of brackish waters into hypersaline waters with negative effects on the breeding of freshwater and brackish species.

The problem of saline infiltration may be exacerbated by reduced runoff and increased withdrawal of fresh water due to increased consumption in many coastal areas.

Changing the species being farmed, choosing euryhaline species and, where possible, moving production facilities away from the coast to more suitable sites, are some of the measures to adapt to this problem.

C - Acidification of water

Ocean acidification will affect various chemical, physical and biological processes. The reduction in pH and carbonate availability in water will affect the formation and dissolution processes of skeletal and shell parts of numerous marine organisms, with possible impacts on survival and fitness (Orr et al., 2005; CIESM, 2008). Among aquaculture species, bivalve molluscs, including clams, mussels and oysters, are the taxonomic group that is most sensitive to acidification. Several recent studies have revealed problems with shell calcification already in the early developmental stages of these organisms, resulting in developmental abnormalities, impaired growth and survival (Gazeau et al., 2010; Range et al., 2011). During the development cycle of bivalve molluscs, the transition phase from the pelagic larval form to the benthic juvenile form is extremely critical and characterised by high natural mortality, so additional environmental stresses could significantly reduce seed recruitment in the wild (Cigliano et al., 2010). For shellfish farming, this problem may, in the future, lead to a reduced availability of natural seed to initiate breeding activities and the necessity of supplying artificial seed produced in hatcheries. Genetic research could contribute to the selection of bivalve mollusc species/strains that are more tolerant to more acidic and less hard waters.

Also in Teleosts, acidification could affect the formation of calcified body parts such as otoliths, spine and fin rays with potential problems on development, swimming ability, feeding and anti-predatory behaviour with long-term effects on survival and growth.

D - Extreme events and water stress

Altered rainfall patterns and flooding lead to a deterioration of water quality, with increased turbidity, nutrient and contaminant loading near river mouths and along adjacent coastlines. Foreseeable impacts on aquaculture will affect shellfish and extensive fish farming. High concentrations of suspended solids could reduce the filtration rates of bivalve molluscs, and excessive nutrient loading could cause eutrophication, water hypoxia/anoxia and toxic algal blooms. An increase in the frequency, but more importantly in the intensity of extreme weather events such as floods, whirlwinds and gales, may have an impact on aquaculture activities carried out along the coastal strip and offshore. Strong sea storms could cause structural damage to breeding cages by breaking moorings, frames and nets, resulting in the loss of breeding plots.

The escape of farmed fish, if significant in terms of frequency and number of animals, could have an ecological and genetic impact on natural populations. The financial losses, both from structural damage and loss of biological material, would be very significant.

3.1.3 Adaptation actions

One threat to the sustainability of aquaculture concerns the effects that climate change may have on this sector. A combination of climatic variables, such as droughts, floods, global warming, ocean acidification, salinity and sea-level rise, can have an adverse effect on aquaculture production. For aquaculture development to be sustainable, its environmental impacts must be significantly reduced (Ahmed & Glaser, 2016). Warming of aquatic habitats (marine and freshwater) and changes in precipitation are expected to have direct and indirect effects on aquaculture, such as changes in the productivity of farmed fish and shellfish as well as the outbreak of diseases (Catalán et al. 2019; Reid et al. 2019). Indeed, water temperature is a key factor influencing the physiology and ecology of farmed species such as fish (Pörtner & Peck 2010; Neubauer and Andersen 2019) and molluscs (e.g. Bayne 2017). Other effects from climate change on aquatic habitats could include: changes in dissolved oxygen concentrations in the water column; the frequency and/or intensity of algal blooms and extreme weather phenomena (Seneviratne et al. 2012) with increased damage to rearing facility infrastructure (Reid et al., 2019); and the nature and frequency of disease events (Jennings et al., 2016).

Adaptation strategies will need to include actions that seek to increase scientific knowledge on the phenology of farmed species and their adaptive and resilience capacities to different pressures related to climate change. It will be important to consider the possibility of diversifying the species to be farmed in relation to the changed environmental conditions and to devise more streamlined and manageable plant structures, with materials endowed with greater elasticity and capacity to withstand extreme weather events for which weather warning and criticality systems are important.

One of the possible climate change adaptation strategies for the aquaculture sector is **Integrated Multi-Trophic Aquaculture (IMTA)** (Sreejariya et al., 2011; Chung et al., 2013; Geere, 2014; Clements & Chopin, 2016).

IMTA constitutes a polyculture system in which the farming of commonly farmed species, generally fish and crustaceans (species fed commercial diets), is combined with the farming of other organisms (extractive species) such as algae and invertebrates (e.g. filter feeders or detritivores) in a single integrated farm (Troell et al., 2009; Chopin, 2011; Chopin et al., 2012) (Figures 3.1.3.A). In this way, waste products from the breeding of one species are recycled to become inputs (feed, nutrients) for another. The basic concept of IMTA aims to create balanced systems for environmental sustainability, economic viability and social acceptability (Barrington et al., 2009).

Currently, IMTA systems are found in over 40 countries on an experimental and commercial basis, including Canada, Chile, China, Japan, the United States and many European countries (Chopin, 2011). In Bangladesh, IMTA has recently considered research and development to diversify production (Sarker et al., 2014; Kibria, 2016).

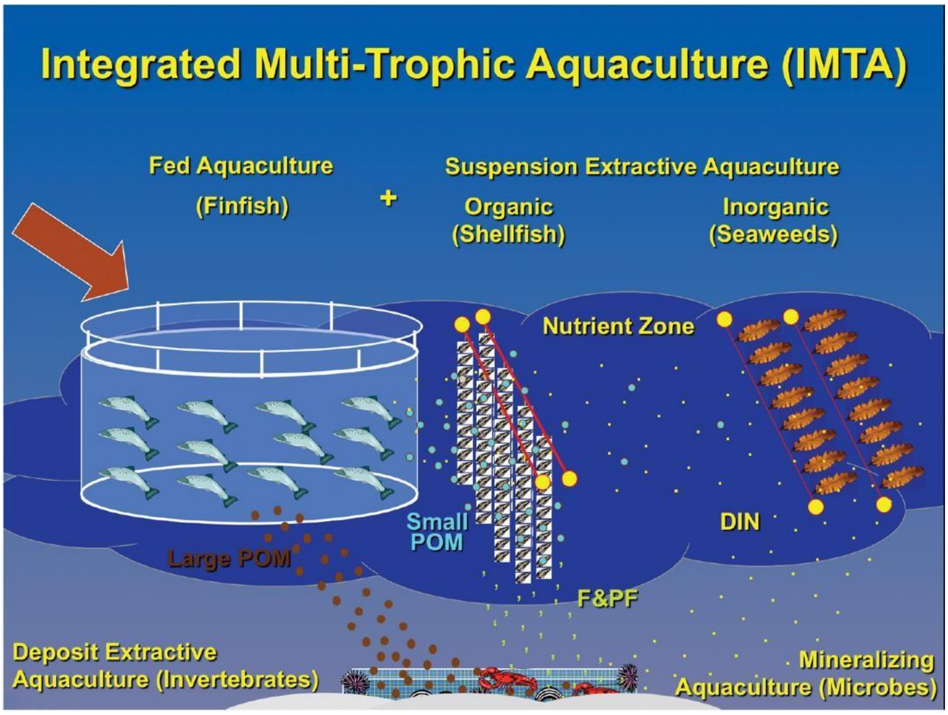

Figure 3.1.3.A – Conceptual scheme of an Integrated Multi-Trophic Aquaculture plant (IMTA) (Chopin, 2017).

Polyculture is not new. It has been an important component of the food industry for millennia, where nutrient recovery between livestock and arable land is still a common practice, and has also been practised for centuries in aquaculture in systems such as the traditional polyculture of stagnant freshwater fish (e.g., Chopin, 2011; 2013; 2020; Chopin et al., 2008)

The concept of modern IMTA was conceived during a seminar in 2004, when Jack Taylor and Thierry Chopin coined the term; since then, more than 1,300 publications on the subject of IMTA have been published. The concept of IMTA is extremely flexible, being simply a theme that accommodates applications in open water or land-based systems (e.g., aquaponics), marine or temperate or tropical freshwater (Chopin, 2013). A typical IMTA configuration has two main components: fed aquaculture species and extractive species (Figures 3.1.3.A). The concept of flexibility has countless variations among adopted species.

IMTA has grown over the last decade as a strategy to mitigate the excessive nutrient load generated by intensive farming, particularly in Asia (Neori et al., 2004), but nowadays it can be a means to ease the expansion of sustainable aquaculture in coastal and marine systems (Neori et al., 2004; Troell et al., 2009).

In the coastal marine environment, IMTA, which combines fish breeding with the breeding of filter-feeding invertebrates, has been tested, with encouraging results, mainly to mitigate excessive water trophism resulting from fish farms. Indeed, the excess of nutrients (eutrophication) causes algal blooms (often with production of mucilage and biotoxins) resulting in anoxia phenomena in the marine environment, unfortunately exacerbated by the warming of waters that reduce oxygen solubility. Therefore, the trend towards diversification of farmed species and relocation of production facilities to the open sea has long been established, with the aim of making mariculture more competitive while reducing its impact on the coastal environment and responding to the new challenges that climate change requires (Abellan & Basurco, 1999; Ahmed & Glaser, 2016). The ability to breed in integrated polyculture species located at different levels of the trophic network, with different biological and functional roles, makes it possible to pursue new opportunities for mariculture. It is indeed possible to combine fish farming with the cultivation of algae or filter-feeding invertebrate organisms, such as poriferous and polychaete, which, in addition to their intrinsic commercial value, can perform a bioremediation function for the surrounding environment (Giangrande et al., 2020; 2021; Gifford et al., 2006; Stabili et al., 2006; 2015; 2023; Longo et al., 2010; 2016).

Polyculture in the marine environment is not a novelty, even in the Italian aquaculture scene (Bombace et al., 1991; 1998). However, the development of IMTA systems with organisms used in the role of bioremediators is still in an experimental phase and mainly concerns laboratory or in-shore systems, whereas algae and bivalve mollusc farming facilities are associated with land-based tanks (Batoli et al., 2003; Franchi & Renzoni, 2003; Giacobbe & Spanò, 2003) that use the wastewater of fish farms. Generally, in these systems, the algal component is used to reduce the nitrogen load, especially in ammoniacal form, produced by fish faeces and the decomposition processes of unused feed; the bivalves, to reduce the rise in the phytoplanktonic component triggered by the increase in nutrients. However, numerous variations to this basic scheme have been trialled, with the use of macroalgae for the removal of nitrogen compounds, grazing molluscs for the purpose of disposing of the macroalgal biomass produced (Franchi & Renzoni, 2003), and echinoderms (e.g., holothurians and sea urchins).

In recent decades, moreover, research has been moving towards the development of innovative IMTA systems that associate fish farming with the farming of different categories of extractive species, both edible (e.g. molluscs, macroalgae) able to contribute to CO_2 sequestration and the subtraction of nitrogen and phosphorous (nutrients), and non-edible (e.g. porifera, polychaetes, ascidians, holothuroids, etc.) able to mitigate the excessive trophism of water resulting from fish farms and mitigate the possible presence of algal biotoxins or pathogens.

The application of the basic ecological concept for the functioning of ecosystems in nature using IMTA systems is based on the principle that a production system recycles waste from one process (breeding of fed species) as raw materials (secondary raw materials, mps) for another production process (breeding of extractive species).

Thus, IMTA creates a virtuous system in terms of circular economy in the mariculture sector, generating multiple benefits (Figures 3.1.3.B):

1) Reducing impacts from fish farming and achieving balanced systems that support the environment;
2) performance improvement;
3) production diversification including by producing additional exploitable biomass;
4) greater social acceptance and new job opportunities;

5) mitigation of the effects of climate change. IMTA is considered an adaptation strategy of the ecosystem approach to climate change (IFAD, 2014). Coastal IMTA in open waters could play an important role in strengthening the resilience of social-ecological systems to climate change.

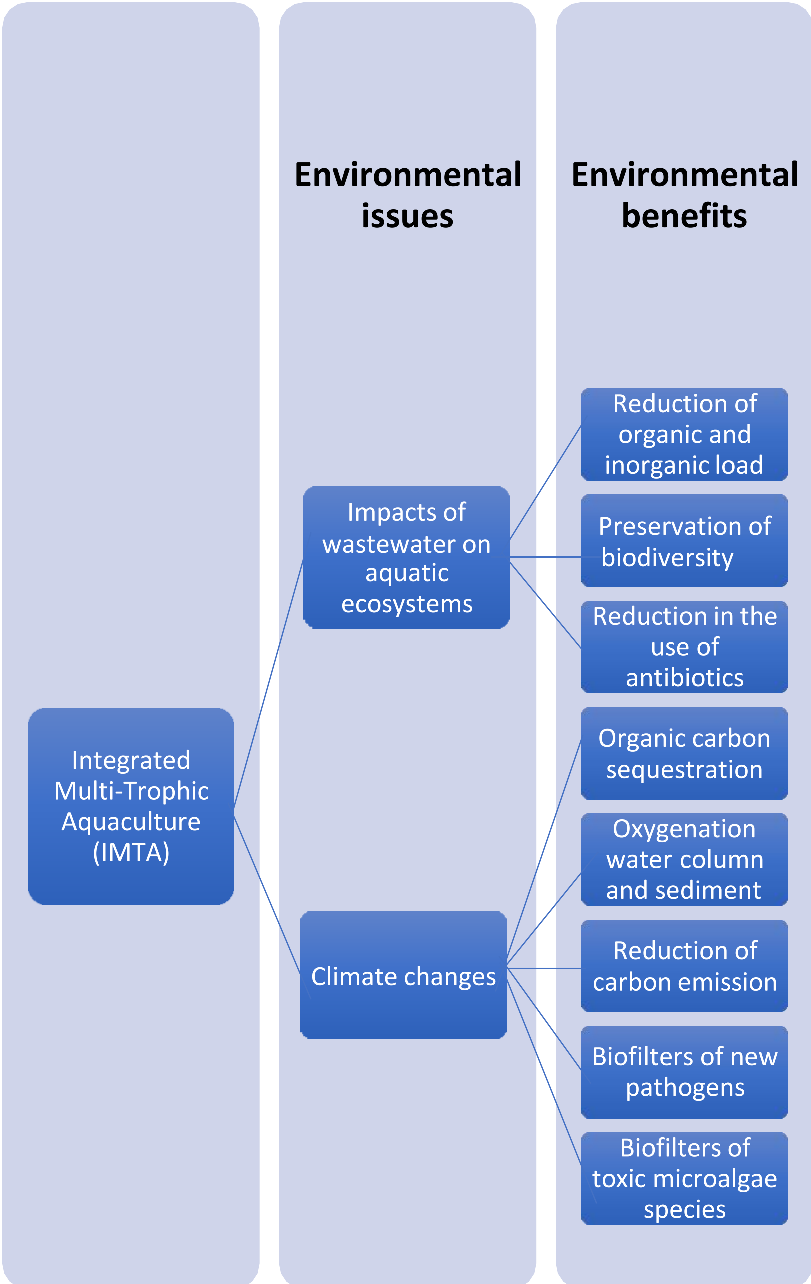

Figure 3.1.3.B – Environmental benefits from the development of IMTA practices in open sea, which contribute to the response to climate change effects.

IMTA can help increase climate change response and adaptation options for Apulian coastal aquaculture.

The implementation of IMTA systems in confined coastal areas, for example, can increase the availability of O_2 produced by photosynthesis by reared macroalgae. In addition, IMTA can reduce O_2 consumption due to the decomposition of organic matter by microorganisms through the bioremediation action performed by reared filter-feeders (Sreejariya et al., 2011).

The availability of dissolved O_2 from the photosynthetic activity of algae can help increase microbial activities within the sediment as well, which then allows for the efficient recycling of nutrients from the decomposition of dead organisms (Bjork et al., 2008). IMTA may also play an important role in reducing CO_2 emissions as algae subtract it for photosynthesis. Seagrass cultures in IMTA systems can also act as sequestrators of stored, sequestered and released organic carbon from coastal ecosystems (Chung et al., 2013).

Integrated mussel farming in IMTA systems due to the carbon sequestration required to build their shells (Wolff & Beaumont, 2011), contributes to the reduction of organic carbon concentrations and consequently to climate change mitigation (Mcleod et al., 2011; Duarte et al., 2013; Siikamtaki al., 2013).

In addition, by diversifying production, IMTA may be able to address the need to adapt to variations in water salinity that may arise locally due to extensive changes in thermohaline conditions resulting from climate change. Indeed, the integrated breeding of bivalves, algae and other euryhaline species, which can tolerate wide variations in salinity, can help to maintain economically viable production lines for farmers.

Algae and all filter-feeding organisms reared in IMTA systems can help keep the water column in good condition by absorbing pollutants, sediment and toxic substances (Chung et al., 2013).

A number of studies have highlighted the link between rising sea surface temperature with increased disease outbreaks for aquatic species and toxic microalgae blooms (Colleen et al., 2016; Zgouridou et al., 2022).

The spread of outbreaks is a clear example of spatial distribution influenced by global warming, resulting in significant mortality events and reduced production of, for example, marine molluscs on Mediterranean coasts (Villalba et al., 2004; 2005). According to recent estimates, despite the differential distribution of bacteria and toxic microalgae species along the Mediterranean coasts, pathogen outbreaks are expected to occur rapidly, particularly due to thermophilic species (Galli et al., 2017). The integrated farming in IMTA systems of filter-feeding species, both edible and non-edible, that are naturally effective biofilters, can help alleviate the risk of disease outbreaks for both farmed species and humans.

Several porifera species have been shown to be effective bioremediators of different categories of microbiological pollutants, organic and inorganic compounds.

Poriferas are predominantly marine benthic invertebrates that are effective filter feeders, and are capable of removing organic particles between 0.5 and 50 microns (dissolved and particulate organic matter, heterotrophic bacteria, heterotrophic eukaryotes, phytoplankton) from water. In general, picoplankton (<2 microns) and in particular bacterioplankton are considered to be the major source of carbon for sponges and can potentially alone supply their diet entirely, especially in coastal waters with high organic content. The high efficiency in the removal of the bacterial component from the water column suggested the possibility of using poriferas in IMTA systems, as bacteria, including potentially pathogenic ones, are usually very abundant in waters with a high organic content, such as bays and areas subjected to aquaculture activities. Investigations conducted both in the laboratory and in the natural environment, including in polyculture pilot plants, have revealed the excellent bioremediation performance of various porifera species against some bacterioplankton components, as well as high organic carbon removal, accumulation and digestion capacities of different bacterial categories.

In an experiment conducted to evaluate the effect that the microbiological accumulation of demospongia *Hymeniacidon perlevis* has on the filtration activity of *Mytilus galloprovincialis* showed important application potential in the field of environmental mitigation in shellfish farms. Indeed, the presence of the sponge demonstrated a positive effect on *M. galloprovincialis*, reducing its accumulation of all bacterial categories considered. The results obtained in the offshore polyculture pilot plant in *M. galloprovincialis* and *H. perlevis* were also extremely promising. The analysis of the considered microbiological parameters (vibrios, coliforms and enterococci) were significantly lower in the mussel and sponge pilot plant area than in the control area. The results encourage the implementation of polyculture systems for mussels and sponges, which would lead on the one hand to an improvement in the microbiological characteristics of farmed mussels, and on the other hand to a mitigation of microbiological pressures in mollusc farming areas (Longo et al., 2016).

IMTA experiences in the Mediterranean Sea in productive mariculture systems have been carried out recently in the course of different research projects. To name a few: from the pioneering work of the 2000 *BIOFAQ* program, "*INTEGRATED Multi-trophic AQUACULTURE*: *A sustainable, pioneering alternative for marine cultures in Galicia*" carried out in 2012 and "*IDREEM, Increasing Industrial Resource Efficiency in European Mariculture*" (7th Framework Program, 2012), to the most current: *Intelligent management system for integrated multitrophic aquaculture (Cordis)* and IDMA *Innovative Development of Multitrophic Aquaculture in Greece*, both launched in 2018. In fact, the experiences still remain at an experimental level, but a marvellous socio-economic analysis is also available in the IDREEM project. Along the Ionian coast of Puglia, the *REMEDIA Life* project *(REmediation of Marine Environment and Development of Innovative Aquaculture: Exploitation of edible/not edible biomass*), financed under the 2016 European LIFE Environment fund, sees the collaboration of Italian research institutions present in the Apulian territory (University of Salento - DiSTeBA; the University of Bari - Department of Biosciences, Biotechnology and Environment; the Institute for Coastal Marine Environment IAMC-CNR of Taranto) and the Maricoltura Mar Grande (MMG) company in Taranto.

The field activities were carried out in the Mar Grande of Taranto in a confined area where impacts from coastal mariculture activities are greatest.

The *REMEDIA Life* project was developed precisely to mitigate the adverse effects of mariculture activities on the environment, thanks to the effectiveness of an innovative IMTA system. This is a rearing system based on a 'new' set of bioremediation organisms that, in addition to mussels and macro-algae, includes other stress-resistant invertebrates such as polychaetes and sponges, whose combined action is more effective than the use of molluscs alone (Figures 3.1.3.C). All of these organisms reared in the vicinity of the fish rearing cages grow without any added food because they 'feed' on the farm's waste, removing the organic (bacteria, toxic phytoplankton and organic matter) and inorganic (nitrogen and phosphorous salts) surplus that would increase the pollution load of the surrounding waters. In this way, waste does not become waste, but is transformed into potentially usable biomass in a 'circular economy' approach. With this project, it has been proven that polyculture, rather than monoculture, is more effective and feasible in a confined environment and that the system can lead to the proper use of waste from fish farming, which then becomes secondary raw materials. In each production cycle, apart from the edible species (fish, mussels/ oysters, macro-algae), non-edible biomasses (polychaete annelids, macro-algae and sponges) with a high commercial value are produced. Production diversification can be an added value for aquaculture enterprises, opening up new markets in relation to the marketing of non-edible biomass. Indeed, the project includes the production of biotechnological compounds in line with 'BLUE GROWTH' themes. Biomasses could be used for the production of innovative feeds, for extracting bioactive compounds useful in the pharmaceutical and nutraceutical fields, for the production of fertilisers and/or marketed in the fishing (bait) and aquarium sectors (Figures 3.1.3.D). In the short/medium term, bioremediation of the mariculture plant's water column and sediments is envisaged, with a considerable improvement in environmental conditions. The system could also lead to improved breeding performance with a reduction in risks associated with bacterial contamination of fish products and mitigation of the effects of climate change in the aquaculture sector. Finally, the *REMEDIA Life* project may also have positive indirect effects on European employment policies and on the participation of the population in decision-making processes (discussion/debate between stakeholders and decision makers).

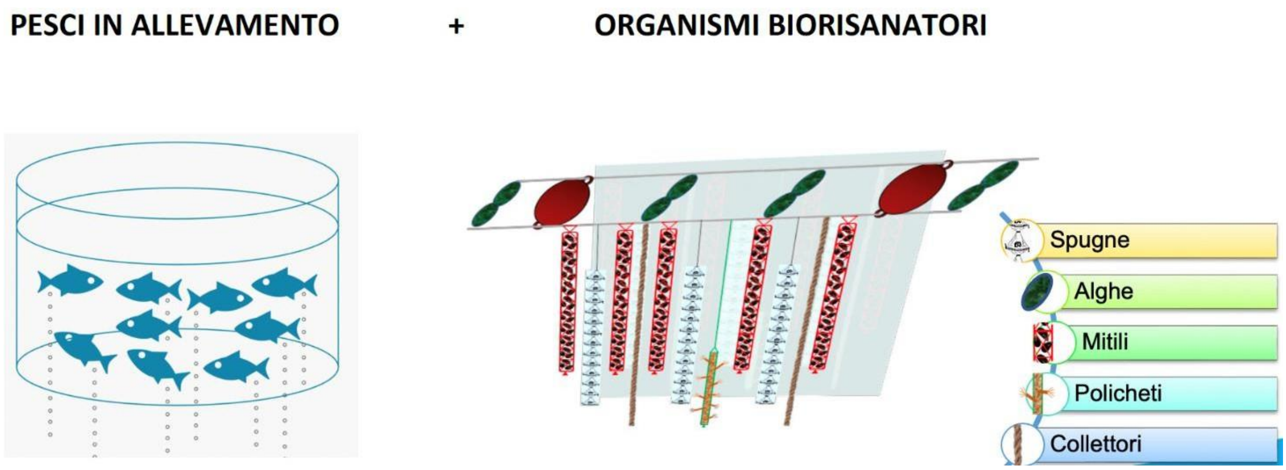

Figure 3.1.3.C – Schematic diagram of the IMTA system, developed for project REMEDIA Life in the Mar Grande of Taranto. Data: breeding fish and bioremediating organisms. Sponges, algae, mussels, polychaetes, collectors.

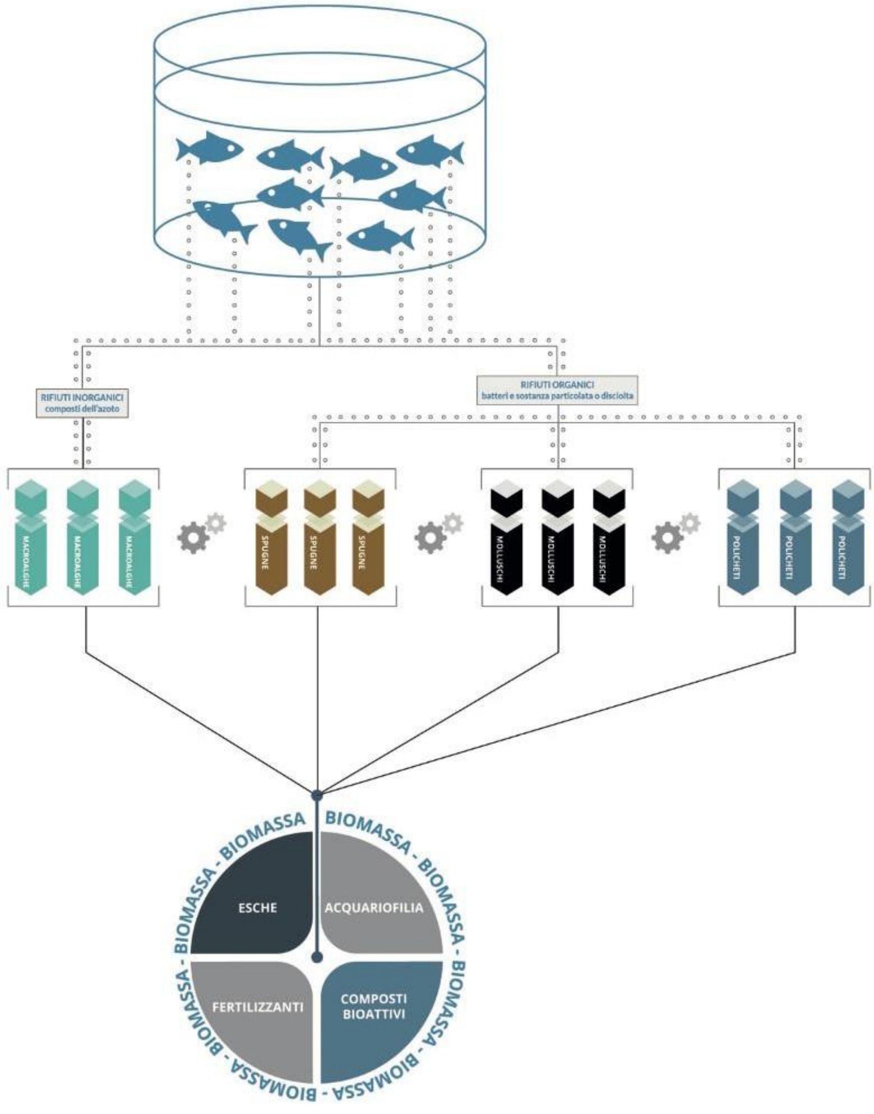

Figure 3.1.3.D – Schematic diagram of the IMTA system, developed for project REMEDIA Life in the Mar Grande of Taranto and possible use of farmed non-edible biomasses.
Data: fishing (bait), aquarium sectors, fertilisers, bioactive compounds.

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3.2 Impacts and adaptation actions for coastal erosion

Coastal erosion can best be defined as the invasion of land by the sea. It is generally evaluated with reference to a sufficiently long-time span, i.e. one that allows temporary phenomena related to individual sea storms and sediment dynamics of a strictly local nature to be neglected.

Coastal erosion can involve three different types of impacts or risks:

- Loss of areas with economic value;
- destruction of natural defences (usually dune systems) even after a single storm event, resulting in potential inland flooding;
- destruction of artificial defence works, resulting in potential inland flooding.

Coastal erosion and development processes have always existed and have, over time, contributed to shaping the coastal landscape by establishing a variety of coastal types. They are also affected by events occurring inland, in areas, sometimes, far away from the coasts. Rainfall and the action exerted by water on the beds of streams, for example, have the effect of moving sediment toward the coast, thus providing essential material for the development of beaches and sand dunes.

Coastal erosion is, generally, the result of a combination of factors, both natural and human-induced, operating on different scales.

Many European coastlines are affected by erosion phenomena, and the extent varies from country to country with overall alarming results. In Italy, an estimated 23 percent of the coastline suffers from erosion (MATTM, 2017), primarily because of the rapid urbanisation to which coastlines and beaches have been subjected in recent decades. Apulia, with its approximately one thousand kilometres of coastline, has also been affected since the 1950s by local and/or widespread sandy coastal erosion phenomena, due to both natural and anthropic factors. The study conducted by the Ministry of the Environment (MATTM, 2017), which includes an analysis of the evolutionary phenomena that occurred at a national level from 1960 to 2012, highlights, consistently with all the studies previously conducted (CNR, 1997; Apulia Region, 2000; Apulia Region, 2007; Apulia Region, 2009; Apulia Region, 2010), the seriousness of the erosive processes taking place along the Apulian coasts. As of 2012 there were, in fact, 128 km of coastline in erosion compared to 121 km in advancement compared to 1960.

The assessment of the condition of the coastline, to be carried out through appropriate monitoring actions, is an essential requirement in the implementation of coastal zone management and planning policies, both for identifying critical areas and for understanding evolutionary trends.

The Protocol on Integrated Coastal Zone Management (ICZM), drawn up with the aim of creating a common European framework to facilitate integrated coastal zone management, promoting a balance between economic development, human use of the coastal zone and environmental protection, identifies coastal monitoring and observation systems as indispensable tools for proper integrated management.

3.2.1 Analysis of the current scenario for the industry

The Apulian Adriatic coastline, digitized on the basis of orthophotos taken in 2017 by the Apulia Region's State Property and Heritage Service, including the Tremiti Islands, stretches for approximately 725 km and administratively falls within five provinces and covers the territory of 43 municipalities.

It should be noted that the perimeter of projecting coastal works (i.e., breakwater piers, breakwater groynes and jetties) on the shoreline was not included in the calculation of lengths. It should also be specified that digitisation on the basis of high-resolution orthophotos (equal to 0.2 m) has allowed a more detailed and precise description of the coastline compared to previous studies (Apulia Region, 2007), with particular reference to rocky coastlines, for which greater values of lengths are observed than had been mapped on the basis of orthophotos with a lower spatial resolution.

Physiographic Units

In the present study, the regional coastline was preliminarily divided into Physiographic Units (Figures 3.2.1). These identify stretches of coastline where solid transport, due to wave motion and coastal currents, is restricted. Generally, physiographic units are bounded by headlands whose conformations do not allow sediment to enter and/or leave the coastline.

In addition to the 'natural physiographic units', 'anthropic physiographic units' were also considered, i.e., the stretches of coastline between a promontory and a sea, port or defence structure, the ends of which are built on seabed depths of more than 10 metres. These works, for all intents and purposes, are longitudinal solid transport dams. For a more detailed analysis, sub-units have been identified within each physiographic unit that are delimited either by small headlands or by sea works whose ends are built on seabed depths of less than 10 metres.

For the coasts of the Apulia region, seven physiographic units were identified: the first starts from the breakwater of the port of Termoli (Molise), while the seventh ends at Capo Spulico (Calabria) (Figures 3.2.1).

Figure 3.2.1 – Apulian coast showing physiographic sub-units.

Morphology of the Apulian Adriatic coast

The Apulian Adriatic coast, digitized on the basis of orthophotos acquired in 2017, including Tremiti Islands, consists mainly of cliffs (29%), sandy beaches (28%), and rocky coast (26%), while along about 9% of the coast anthropogenic works were found (Figures 3.2.2)

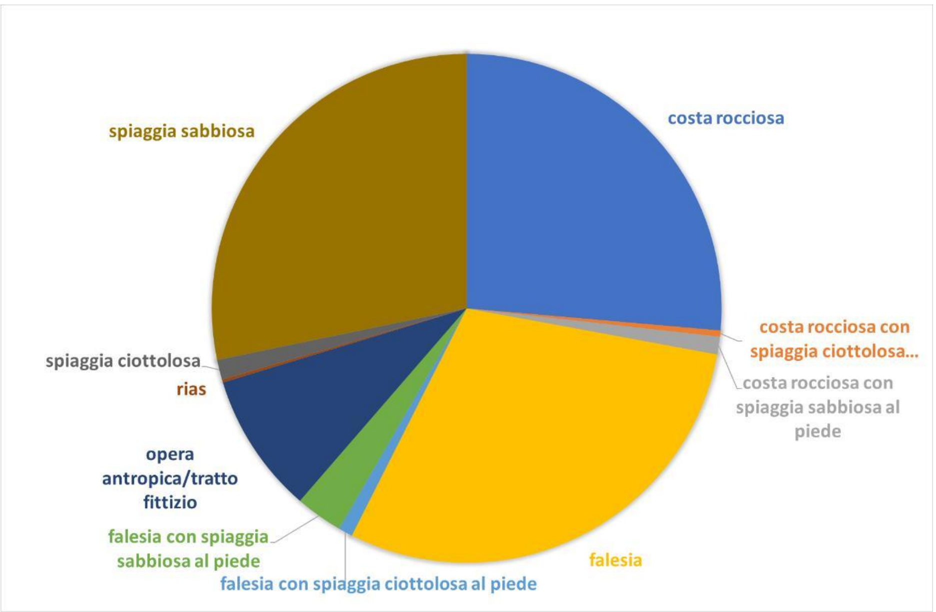

Figure 3.2.2 – Morphology of the Apulian Adriatic coast.

Data: rocky coast, rocky coast with pebbly beach, rocky coast with sandy beach, cliff, cliff with pebbly beach, cliff with sandy beach, anthropogenic works / artificial section, Ria, pebbly beach sandy beach.

Table 3.2.1 and Figures 3.2.3 show the total linear extent (in km) of the different types of coastal morphology, as specified in the Regional Coastal Plan, updated with the new digitisation performed on aerial shots in 2017.

Morphology	**Type A (km)**	**Type B (km)**	**Type C (km)**	**Type D (km)**	**Type E (km)**	**Type F (km)**	**Type G (km)**	**Type H (km)**	**Type I (km)**	**Type L (km)**	**Total (km)**
Isole Tremiti	16.5	0.0	0.2	14.5	0.0	0.0	0.0	0.0	0.0	0.0	31.1
SUF1.1	5.8	0.0	0.3	0.8	0.0	0.0	1.7	0.0	1.0	57.5	67.1
SUF1.2	0.0	0.0	0.0	2.4	0.0	0.8	0.4	0.0	0.0	8.4	12.0
SUF1.3	0.0	0.0	0.0	19.4	0.0	1.1	0.3	0.0	0.0	8.2	29.0
SUF1.4	0.0	0.0	0.0	7.3	0.0	0.3	1.0	0.0	0.0	4.5	13.1
SUF2.1	0.0	0.0	0.0	9.8	0.1	0.5	0.0	0.0	0.3	0.0	10.8
SUF2.2	0.2	0.0	0.0	30.1	4.7	1.6	1.6	0.0	2.7	0.1	40.9
SUF2.3	1.6	0.0	0.0	0.0	0.0	0.0	8.2	0.0	0.0	33.0	42.8
SUF2.4	0.3	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	14.2	16.4
SUF2.5	7.1	0.9	0.1	5.9	0.7	0.5	9.4	0.0	2.1	7.9	34.7
SUF2.6	16.4	1.3	0.0	0.5	0.0	0.2	11.6	0.0	0.9	1.3	32.3
SUF3.1	48.3	0.5	2.2	14.6	0.1	0.3	10.5	0.0	2.2	0.4	79.0
SUF3.2	49.7	0.0	2.0	36.4	0.0	9.4	3.7	0.0	0.0	19.4	120.6
SUF4.1	9.2	0.0	0.5	0.0	0.0	0.0	0.8	0.0	0.0	0.1	10.6
SUF4.2	0.3	0.0	1.4	0.0	0.0	0.0	5.2	0.0	0.0	2.3	9.2
SUF4.3	11.4	0.1	1.4	25.7	0.9	7.0	6.9	0.0	0.0	47.6	101.0
SUF4.4	5.0	0.0	0.1	4.2	0.0	0.0	0.1	0.0	0.0	0.0	9.3
SUF5.1	19.5	0.0	0.0	42.6	0.0	0.1	1.5	1.4	0.0	0.0	65.1
Adriatic Total	**191.3**	**2.9**	**8.1**	**214.1**	**6.5**	**21.8**	**64.9**	**1.4**	**9.1**	**204.9**	**725.0**

where:

rocky coast	Tipo A
rocky coast with pebbly beach	Tipo B
rocky coast with sandy beach	Tipo C
cliff	Tipo D
cliff with pebbly beach	Tipo E
cliff with sandy beach	Tipo F
Anthropogenic works / artificial section	Tipo G
Ria	Tipo H
pebbly beach	Tipo I
sandy beach	Tipo L

Table 1.2.1 - Morphology of the Apulian Adriatic coast divided by physiographic sub-units.

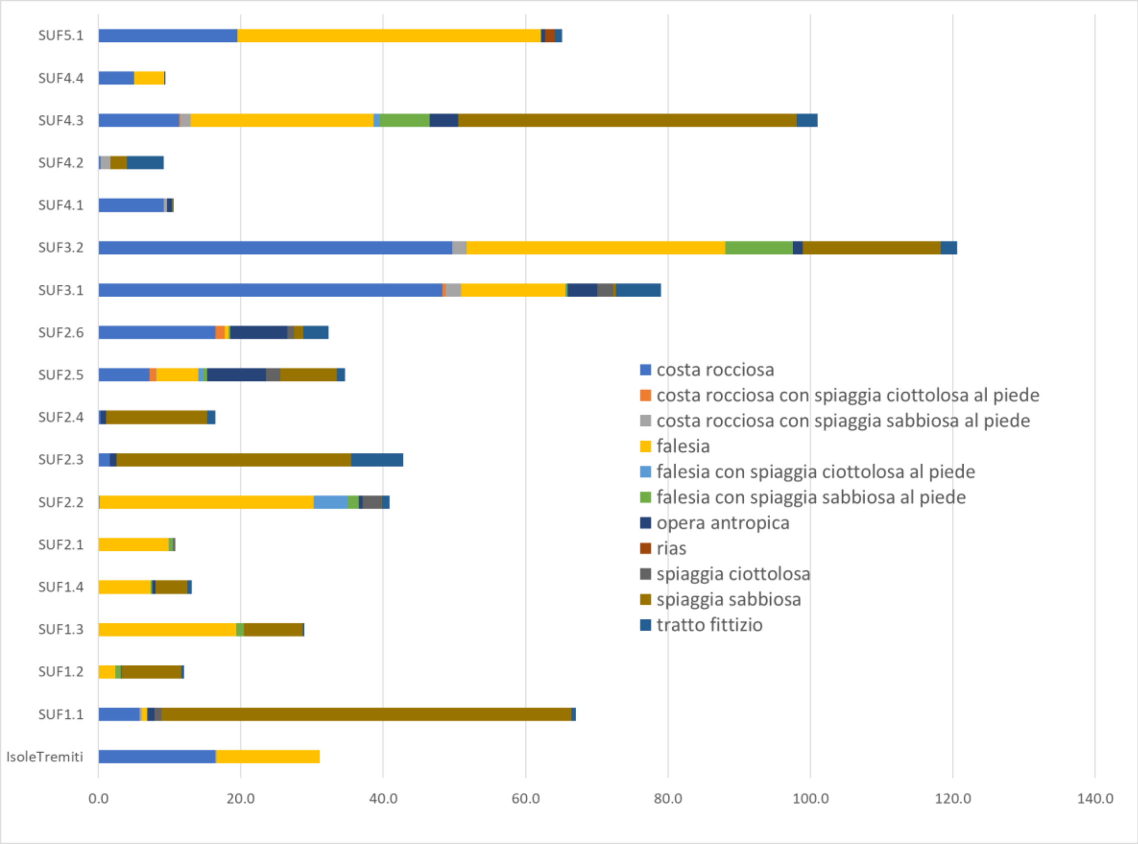

Figure 3.2.3 - Morphology of the Apulian Adriatic coast divided by physiographic sub-units (km). Data: rocky coast, rocky coast with pebbly beach, rocky coast with sandy beach, cliff, cliff with pebbly beach, cliff with sandy beach, anthropogenic works, Ria, pebbly beach sandy beach, artificial section.

Reconnaissance and mapping of beaches was carried out, in order to assess their evolution, both on sandy or pebbly beaches and along the rocky coast (high and low) with sand or gravel beach at the foot (Table 3.2.2).

Type of coast
Rocky coast with pebbly beach
Rocky coast with sandy beach
Pebbly beach
Sandy beach
Sandy-pebbly beach
Cliff with sandy beach

Table 3.2.2 – Types of coasts taken into consideration for the evolutionary analysis.

Along the regional shorelines falling into the above typologies, the shoreline was extracted and the beach area between the shoreline and the backshore boundary was mapped.

Beach mapping enables both the evaluation of sandy shoreline widths and the monitoring of land areas lost to erosion phenomena.

Downstream of beach mapping, it was possible to calculate some dimensional parameters such as area, length and width. In fact, the measurement of the width of a beach turns out to be, along with changes in shoreline position, a significant parameter in the evaluation of evolutionary phenomena. The characteristic beach parameters calculated in the individual SUFs that were analysed are shown in Table 3.2.3.

Name_UF	Name SUB UF	Beaches length (km)	Beach polygon area (kmq)	Average beach width (m)
1	S.U.F.1.1 Chieuti-Rodi Garganico	58.6	1.51	26.30
	S.U.F.1.2 Rodi Garganico -Peschici	9.4	0.24	24.83
	S.U.F.1.3 Peschici-Vieste	9.2	0.42	43.95
	S.U.F.1.4 Vieste/Testa del Gargano	4.6	0.32	65.18
2	S.U.F.2.1 Vieste/Pugnochiuso	1.0	0.02	18.63
	S.U.F.2.2 Vieste/Pugnochiuso-Manfredonia	8.9	0.13	14.37
	S.U.F.2.3 Manfredonia-Margherita di Savoia	37.5	0.86	25.30
	S.U.F.2.4 Margherita di Savoia - Barletta	14.3	1.02	71.97
	S.U.F.2.5 Barletta-Molfetta	12.2	0.21	16.95
	S.U.F.2.6 Molfetta- Bari	4.0	0.07	17.56
3	S.U.F.3.1 Bari-Monopoli	4.9	0.09	17.83
	S.U.F.3.2 Monopoli- Brindisi/Punta Penne	31.4	0.57	18.55
4	S.U.F.4.1 Brindisi/Punta Penne-Brindisi/Punta Riso	0.7	0.01	0.00
	S.U.F.4.2 Brindisi/Punta Riso-Brindisi/Torre Cavallo	2.3	0.03	15.28
	S.U.F.4.3 Brindisi/Torre Cavallo-Otranto/Porto di Otranto	59.8	1.16	19.92
	S.U.F.4.4 Otranto/Porto di Otranto-Otranto/Capo d'Otranto	0.0	0.00	0.00
5	S.U.F.5.1 Otranto/Capo d'Otranto-Gagliano del Capo	0.1	0.00	30.31
TOTAL_		**259.0**	**6.7**	**25.5**

Table 3.2.3 – Characteristics parameters of the mapped beaches divided by physiographic sub-units.

Methodology for shoreline evolutionary trend analysis

The coastline can ideally be defined as the land/sea interface (Dolan et al., 1980), but despite the simplicity of this definition, identifying its location is very complex because of its extreme variability, both short- and long-term.

The most common methodology of extracting, from an image, visually identifiable features is based on interpretation by an operator, who digitises on the images, once orthorectified and georeferenced, the feature he recognises as a coastline. The identification is, therefore, non-objective as it is based on the operator's expertise and his specific knowledge of the site being analysed. It follows that whatever indicator is chosen from those in this category, it is, by its very nature, subjective and non-repeatable.

When comparing multiple coastlines extracted from orthophotos, additional issues may arise from the geo-referencing of the images themselves, the different Digital Terrain Model used for orthorectification, and the different resolution of the images used.

The analysis of coastal evolution was carried out on the basis of IGM 1:25,000 cartography and three sets of images made in 1992 (SID orthophotos), 2005 (TerraItaly TM NR colour orthophoto of the 2005 flight of the Apulia Region) and 2017 (as made available by the State Property and Heritage Section - Coastal and Port Property Service of the Apulia Region), respectively.

The most recent sets consisted of high-resolution images (with pixel size less than one metre), which enabled detailed and timely analysis of the Apulian coastline (Table 3.2.4).

Set of images	Shooting period	Resolution on the ground (m)
Cartography IGM 1:25:000	1960	-
Orthophoto SID	1992	1
TerraItaly TM NR	2005	0.5
Orthophoto Puglia Coste	August 2017	0.2

Table 3.2.4 – Cartography used for extracting shorelines.

The coastlines related to 1992, 2005 and 2017 were digitised manually from the orthophotos. In order to minimise the risk of making errors due to different parties interpreting the data differently, the extraction was performed by the same experienced operator.

In order to evaluate the evolving features, surface polygons bounded by the intersections of the two coastlines being considered were identified. These polygons represent the areas of advancing or retreating coastline during the time interval under analysis.

Of all the polygons thus created, only those that contained at least one point of distance, in absolute value, between the coastlines of at least 10 m were selected, while the remaining polygons were not considered in the evolution analyses, considering the areas enclosed by them to be stable. Only in the 1960-1992 comparison was a minimum range of variation of 30 m considered.

This criterion made it possible to obtain results unaffected by the inevitable approximations resulting from the shoreline digitisation procedure and to exclude ordinary changes related to seasonal weather cycles from the analyses.

From the perimeter of each polygon thus selected, the shoreline segments belonging to the most recent shoreline were extracted; these segments were then defined as in retreat or advancement.

From the set of segments thus obtained, further selection was made based on shoreline morphology; rocky shorelines and cliffs were considered stable, while sandy or gravelly shores and high shorelines with sand or gravel beach at the foot were evaluated for evolution analyses. To complete the analysis, the sizes of the tracts thus selected were calculated.

Analysis of evolutionary phenomena

The analysis of the current state of the Apulian coastline, carried out on the basis of the coastlines extracted from the available cartography, has shown that the regional coastline, during the period analysed, has been affected by significant problems of retreat of the exposed beach.

The combined results for the entire Apulian Adriatic coast, shown in Table 3.2.5, show that coastal erosion of the Apulian Adriatic coast is certainly not a recent phenomenon, as 103 km of sandy coastline (accounting for 40 percent of the sandy coastline) was affected by retreat during the period 1960-1992 (Figures 3.2.4).

Figure 3.2.4 – Variation in shoreline from 1960 to 1992 (30m range).
Data: progress and erosion.

In the period between 1992 and 2005, erosive phenomena affected only 23 percent of the sandy coastline (60 km) (Figures 3.2.5), while in the period from 2005 to 2017, a significant exacerbation of erosive phenomena emerged, with the lengths of eroding stretches of sandy coastline almost doubling in recent years (97 km or about 38 percent of the total) (Figures 3.2.6).

Figure 3.2.5 – Variation in shoreline from 1992 to 2005 (10m range).
Data: progress and erosion.

Figure 3.2.6 – Variation in shoreline from 2005 to 2017 (10m range).
Data: progress and erosion.

It can be seen that erosive processes continue, not only on areas previously affected by the phenomenon, but different and entirely new critical areas are emerging throughout the regional coastline. In addition, it should be pointed out that in many cases the trend has been limited by the presence of coastal protection structures that prevent shoreline retreat and irreversible coastal changes.

UF	SUF	1960-1992 Retreat (%)	1992-2005 Retreat (%)	2005-2017 Retreat (%)
UF1	SUF1.1	24.4	24.2	43.9
	SUF1.2	28.2	17.6	46.9
	SUF1.3	0.0	14.7	30.6
	SUF1.4	5.3	24.4	36.1
UF2	SUF2.1	0.0	0.0	0.0
	SUF2.2	0.0	6.6	19.0
	SUF2.3	42.9	32.2	37.8
	SUF2.4	42.8	47.8	36.5
	SUF2.5	25.5	21.0	26.6
	SUF2.6	0.0	1.2	17.9
UF3	SUF3.1	0.0	7.0	0.8
	SUF3.2	63.3	3.5	56.6
UF4	SUF4.1	33.2	0.0	0.0
	SUF4.2	0.0	0.0	66.2
	SUF4.3	68.2	30.3	30.8
	SUF4.4	0.0	0.0	0.0
UF5	SUF5.1	0.0	0.0	0.0
Total		39.9	23.1	37.6

Table 3.2.5 – Comparison of percentages of retreating sandy shorelines in the periods 1960-1992, 1992-2005 and 2005-2017.

Looking at the behaviour of individual physiographic units, it should be highlighted that, in terms of the percentage of sandy coastline in retreat, the most severe situations were found in UF1, UF3 and UF4, although, in general, the entire Adriatic side of the regional coastline shows significant criticalities. It should also be pointed out that UF1 and UF3 have shown a marked deterioration in the most recent period (Figures 3.2.7). Also, in terms of lost areas, the most critical situations were identified in UF1 and UF3.

Analysis of studies since the PRC has, furthermore, shown that the situation of sandy shorelines has deteriorated sharply and suddenly starting in the period between 2008 and 2010 (Bruno et al., 2014). Indeed, in 2008 the situation still appeared on average stable compared to 2005, although in some UFs erosion phenomena had already manifested themselves to a great degree.

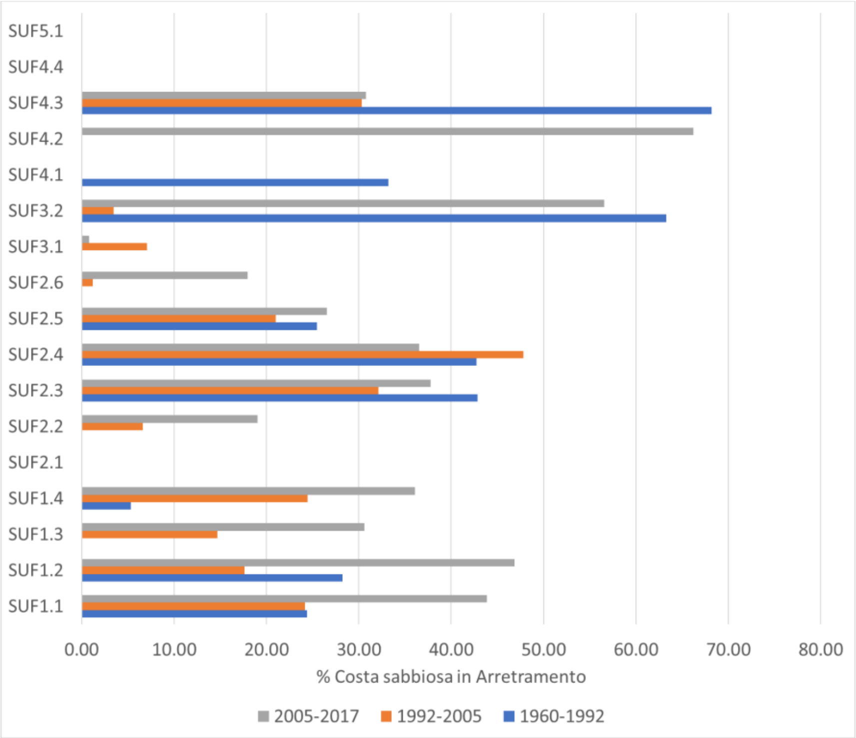

Figure 3.2.7 – Retreating sandy shoreline during the different period analysed.

The increase in the lengths of eroding shorelines can only be partially attributable to the enlargement of the phenomenon to stretches adjacent to already retreating beaches, while more often there has been the emergence of new crisis situations along the entire regional coastline. Many of these new crisis stretches, moreover, have shown a marked erosive trend that has led to shoreline retreats of even more than 30 m (Figures 3.2.8).

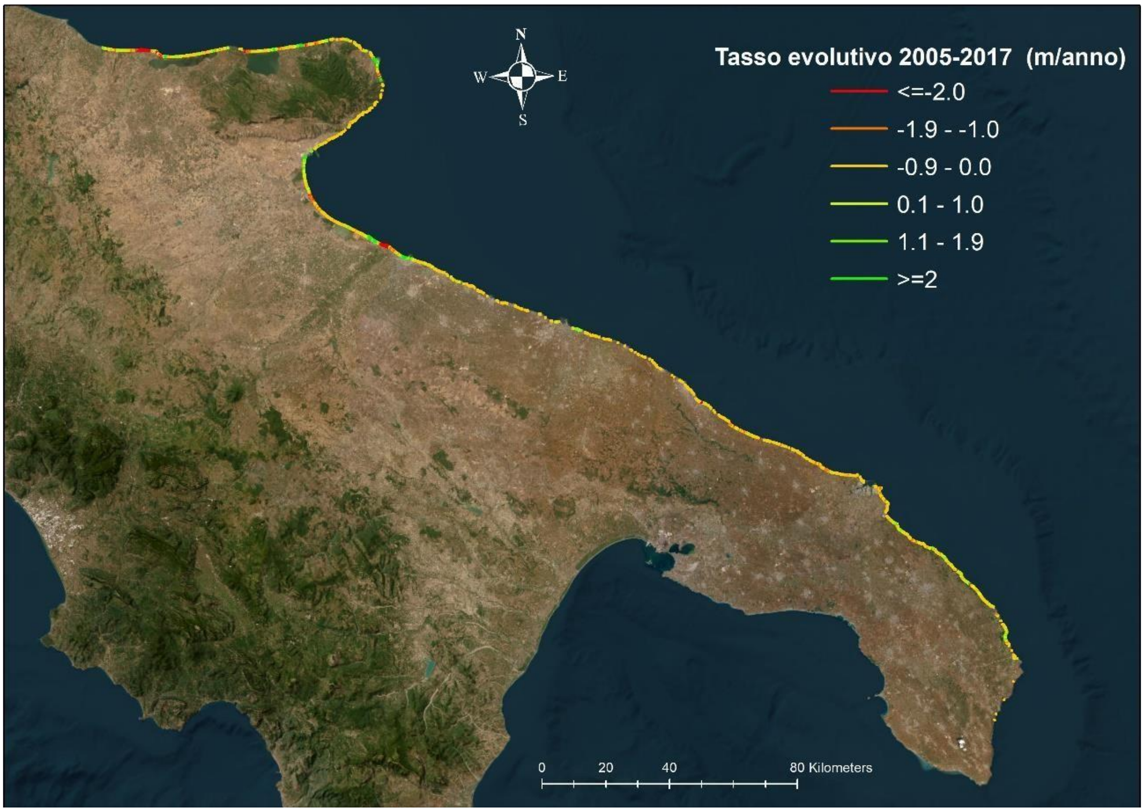

Figure 3.2.8 – Evolutionary annual rate of the Apulian Adriatic coastline in the reference period 2005-2017.

The increase in the lengths of eroding shorelines is only partially attributable to the enlargement of the phenomenon to stretches adjacent to beaches already in crisis (examples include the shorelines of Foce Fortore, Foce Ofanto, the shoreline of the Municipality of Lecce, the Cesine, Torre Mozza), while more often there has been the appearance of new crisis situations (Rodi Garganico, Torre Canne, Torre Guaceto).

The analyses carried out over the different periods clearly show that the phenomenon of coastal erosion on the regional coastline cannot be traced back to seasonal episodes, as the erosive trend, which was already very marked in previous years, continues to increase and impact increasingly large stretches of coastline (Bruno et al., 2020; Bruno et al., 2021).

Many of the currently eroding stretches of shoreline are of considerable environmental and socio-economic value and, therefore, further investigations are advantageous, to identify their root causes in order to pinpoint the most appropriate interventions for shoreline protection.

3.2.2 Analysis of expected impacts

Sea level rise caused by climate change could have several consequences on Italian coastal areas in the medium and long term. The strong anthropisation of Italy's coastal areas has led to an increase in the areas exposed to coastal risk, particularly in areas under the sea level, or with a high density of urbanisation and population.

The rise in mean sea level due to climatic factors is also locally compounded by the loss of elevation due to the compacted clay and sand layers of the subsoil (subsidence). Vertical land movement locally exacerbates the global phenomenon due to climate change (SNPA, 2021).

Among the projected impacts on coastal areas, those related to erosion and flood risk were analysed:

- Intensification of coastal erosion processes: particularly for low-lying beaches resulting in a retreat of the coastline;
- Increased risk of flooding (from sea and land), loss of habitats and deterioration of water quality: for territories located at or below mean sea level (e.g. lagoons, shorelines, rivers, plains, built-up areas and their infrastructure and cultural heritage);
- Variation in the frequency and intensity of extreme events: although it is possible that the frequency of sea storms may not increase significantly, it is likely that the predicted sea level rise will result in much more severe impacts, increasing both the severity of the effects of sea storms and the likelihood that they will have a negative impact on the coast (e.g. impacts on habitats, coastal zone use, population).

Reduced availability of beaches

Probabilistic projections of sandy shoreline dynamics during the 21st century were produced by Vousdoukas et al. (2020) by combining projected values of sea level rise (SLR), spatial changes in the slope of the active beach profile, trends in coastal environmental change, and future changes in meteorological drivers such as sea storms and waves.

Long-term shoreline evolution D is expressed as the combined result of two components:

$$D = R + AC$$

where R is the response of the shoreline to SLR and AC is the variation of the shoreline in response to environmental factors. In most cases, the AC component is related to human interventions that alter the sediment balance and/or transport processes of coastal systems, but also includes natural transitions due to other causes, such as meteorological changes, persistent changes in transport along the coast, or geological factors.

The AC component was obtained by analysing, using a probabilistic approach, historical trends of shoreline change from two recent remote sensing datasets (Luijendijk et al., 2018; Mentaschi et al., 2018). In detail, these historical trends were derived from the automated analysis of Landsat images acquired during the period from 1984 to 2015.

The retreat R caused by SLR was estimated using a modified Bruun rule (Bruun, 1962) and considering projections of future sea levels under the RCP4.5 and RCP8.5 emission scenarios (Jackson and Jevrejeva, 2016; Jevrejeva et al., 2014).

SLR projections up to 2100 were estimated using a probabilistic approach that combines the main factors contributing to SLR: Long-term alteration of ocean density change, globally averaged steric sea level change, dynamic sea level change, surface mass balance of ice from glaciers and polar ice sheets, surface mass balance and ice sheet dynamics of Greenland and Antarctica, land-water storage and glacial isostatic adjustment (Jackson& Jevrejeva, 2016). It should be noted that in the SRL calculation, small-scale local vertical ground movements, such as, for example, ground subsidence due to groundwater pumping, are not included.

Bruun's rule is based on the concept that the morphology of a beach tends to adapt to the prevailing wave climate and depends on the variation in sea level and the slope of the shoreline.

The slope of the beach in question was estimated by considering the depth of closure offshore (Hallermeier, 1978; Nicholls et al., 1998) based on wave height projections (Mentaschi et al., 2017). Therefore, the beach profile (Athanasiou et al., 2019) was estimated by combining topography from the MERIT digital elevation model (Yamazaki et al., 2017) with bathymetric data from the GEBCO dataset (Weatherall et al., 2015).

Information on the location of sandy beaches along the global coast was available from a recent study (Luijendijk et al., 2018).

The study focuses on sandy beaches on the global coastline, along which transects with a 500 m pitch were drawn. For each transect, shoreline displacements at 2050 and 2100 were calculated using the RCP4.5 and RCP 8.5 scenarios, assuming unlimited backshore space. This assumption obviously has some distorting effects, since where some natural coastal systems are characterised by large beach widths so that any value of retreat is possible, in others there may be a strong limitation determined by the presence of anthropic works or physical barriers.

In order to analyze the effects of climate change along the Apulian Adriatic coast, data falling within the area under study was extrapolated (Figures 3.2.9). In particular, the median values of long-term displacements (P50) were analysed.

According to the study analysed, the Apulian Adriatic coast is at high risk of erosion under both scenarios considered (Figures 3.2.10). It is noted that the expected retreats, given the already limited widths of the Adriatic beaches on average, could in some cases lead to the disappearance of the beaches now present.

Figure 3.2.9 – Erosive rates of the coastline in 2050 in scenarios RCP4.5 and RCP8.5.

In spite of the limitations previously highlighted in the study, to which discordances in the classification of coastal morphology are added in a detailed analysis, the study provides clear evidence of the serious risk of the coastline retreating with the consequent impoverishment of the already limited Adriatic sandy strip. Moreover, this trend is also perfectly in line with what has emerged from the analysis of the recent evolution of beaches (Figures 3.2.8), along which alarming erosion rates have emerged, which are likely to increase further due to the rise in the mean sea level expected in the coming decades.

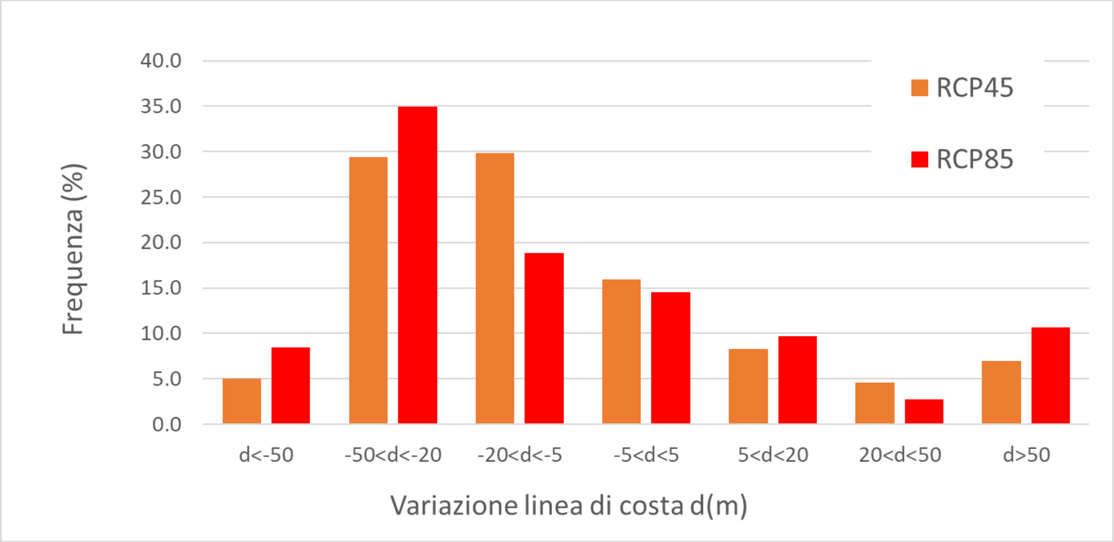

Figure 3.2.10 – Variation frequency of the coastline in 2050 in scenarios RCP4.5 and RCP8.5.

Damage from extreme weather events

Marine erosion and flooding risks already pose a serious threat to coastal areas, and this trend will worsen in the future due to climate change and increasing urbanisation processes (Nicholls et al.,2007; IPCC, 2014; Nicholls et al.,2016).

The natural environment and sustainability of coastal areas are becoming increasingly degraded by erosion and flooding hazards that are enhanced by climate change (Hinkel et al., 2009; Torresan et al. 2012).

The evolution of sandy beaches was projected under different scenarios, and an overall erosive trend of sandy beaches was predicted to increase over time and with the intensity of the scenarios (RCP 4.5 and 8.5) (Vousdoukas et al., 2020).

By the end of the century, according to RCP scenario 8.5, approximately 63% of the world's sandy beaches in low-lying coastal areas with high population density could be affected by erosion. In addition, a significant increase in coastal areas exposed to episodic marine flooding has been reported, resulting in impacts on a larger population (Neumann et al., 2015; Vousdoukas et al., 2018).

The increasing population concentrations in coastal areas have an adverse effect on the coastal ecosystem due to changing land use and overexploitation of natural resources (Nicholls et al.,2016; Zanuttigh et al., 2014; Van Dongeren et al., 2018), also increasing exposure to coastal hazards. Consequently, the ability to adapt to and overcome a dangerous event, known as coastal resilience, is reducing this exploitation and allowing coastal systems the long recovery times they require.

Increased frequency and intensity of extreme events

Waves exhibit a complex response to climate change, which can have a direct influence on the variables related to their generation, transformation and dissipation (e.g. wind patterns). Ocean waves, in combination with other marine processes potentially influenced by long-term climate dynamics (e.g. sea level rise), have been identified as one of the key drivers of coastal climate (IPCC, 2013; IPCC, 2019).

Several studies have analysed regional or global-scale projections of wave climate, with the aim of identifying the long-term effects of climate change on ocean waves, focusing on annual average values and annual maximums of significant wave heights and periods. The robustness and reliability of the predicted change in wave climate is still a subject of debate (Morim et al., 2019). In general, there is a greater degree of consensus on the expected change in mean annual values, while the trend in extreme events has greater uncertainty (Lobeto et al., 2021).

On a global scale, the results of wave climate projections from 91 different sources showed a general agreement on a decreasing trend for annual mean values of significant wave heights in the Mediterranean Sea, while with regard to extreme wave height values, no general consensus was found (Morim et al., 2018).

The analysis of projected wave climate change in the PRC8.5 scenario in the Mediterranean Sea showed a decreasing trend in annual averages and annual maximums of significant wave heights and mean periods in most of the Mediterranean basin (De Leo et al., 2021).

3.2.3 Adaptation actions

Studies aimed at assessing climate impacts on the coastal strip have highlighted that most coastal areas across the planet, and particularly in Italy, are at risk of erosion and flooding due to marine ingress caused by rising sea levels (Neumann et al., 2015; Vousdoukas et al., 2018). This risk is the interaction between potentially hazardous environmental phenomenologies and human activities.

In order to effectively address and reduce the impacts of climate change on coasts, it is necessary to use adaptation interventions.

Adaptation has been defined as 'a process of adjusting a system, environmental or socio-economic, to minimise the negative consequences and exploit the positive opportunities of a disturbance'.

The National Climate Change Adaptation Plan (NCCAP 2022) identifies three types of planned adaptation with respect to climate change, and some of the solutions applicable on the coastal strip are listed below:

Green measures

Actions with a materiality and structural intervention component that differ from grey measures as they propose solutions aimed at the sustainable use or management of natural services, including ecosystem services, in order to reduce the impacts of climate change (NCCAP 2022, ADRIADAPT, Morris et al., 2018).

- *Nature based solution* (NBS) aimed at reducing the hazard and/or exposure to coastal flooding and erosion;
- Protection, restoration, and management of coastal wetlands;
- Protection and restoration of Posidonia oceanica seagrass beds;
- Construction and reinforcement of dunes;
- Unbuildability of the coastal strip;
- River restoration and rehabilitation and river sediment management.

Grey measures

Actions relating to the improvement and adaptation to climate change of facilities and infrastructures, which can in turn be divided into actions on facilities, materials and technologies, or on infrastructure or networks (NCCAP 2022, ADRIADAPT).

- Beach nourishment;
- Interventions for elevation and extension of coastal territory;
- Parawalls and docks;
- Reef defense works (groynes, detached reefs, artificial reefs);
- Stabilisation and strengthening of cliffs (high coasts);
- Marine flood barriers.

Soft measures

Actions that do not require direct structural and material interventions but are nevertheless preparatory to their implementation, contributing to the creation of adaptive capacity through increased knowledge or the development of a supportive organisational, institutional and legislative environment (NCCAP 2022, ADRIADAPT).

- Unbuildability of the coastal strip;
- Marine protected areas;
- Adaptation through integrated coastal zone management plans and programs;
- Planned retreat;
- Modelling, monitoring and forecasting systems;
- Information and education of citizens on climate change and its consequences;
- *Early warning* systems.

A correct approach to coastal management should take into account the concomitance of causes, both global and local, that contribute to a situation of beach erosion and flooding of coastal areas already currently at risk.

Analyses on the evolutionary dynamics underway along the Apulian regional coastline have in fact revealed the presence of numerous stretches of low-lying coastline in retreat, for a total length of around 97 km along the Adriatic coast. Due to the extent of these phenomena and the local nature of many of them, intervention on all stretches with erosive tendencies does not seem realistically feasible, also in view of the need to preserve the natural coastal environment as much as possible. The use of strict interventions should therefore be very limited, especially in areas of high naturalistic and landscape value (Cantasano et al., 2023).

The need to protect the coastline, together with the need to preserve the landscape, natural and environmental value that characterises the regional coast, therefore suggests resorting as much as possible to soft structural interventions such as beach nourishment, possibly protected, and, locally, to seasonal sediment movement on the beach. Locally, NBSs aimed at mitigating erosion and marine inundation could be used (Morris et al., 2018, Chausson et al., 2020)

Such interventions would favour the public enjoyment of the coastal strip and would be a significant driver for the development of tourist movements by enhancing territories facing the current situations of impoverishment of coastal areas that could lead, over time, to a decrease in tourist flows.

The tendency should be not to dissipate energy and money to counter erosive phenomena, again and again, but to implement interventions to regulate and guide the evolutionary processes of the coast, in some cases planning a "setback strategy." For example, near beaches that have not yet undergone urbanisation, building should only be allowed in areas where erosion is absent or at least less intense. Alternatively, such areas could be built on by maintaining a large no-building buffer zone. In the latter case, it is advisable to allocate the building section of the shoreline closest to the sea to lower-cost projects with a greater potential for renovation and/or conversion.

Interventions of considerable importance also involve re-establishing or, at least, stabilising river flows to the sea, and stopping mining activities in riverbeds that selectively reduce solid flows. Interventions in river basins, however, must be carried out considering the possible effects their implementation would have on beaches.

Moreover, special attention must be paid to managing the river mouth areas, which represent the key to the coastlines. Indeed, the construction of maritime works (jetties, breakwaters, etc.) in these areas, which could capture the sediments transported by the river, thus interrupting the supply of adjacent beaches, must be avoided.

Another important adaptation measure is the reconstruction of dunes, or the restoration and preservation of existing ones (Fernández-Montblanc et a., 2020). Very often, in fact, large portions of coastal dunes are demolished, ignoring the fact that they represent a reserve of sediment that is used to replenish the beach in the event of a storm.

However, it should be emphasised that beach erosion, due to the net decrease in sediments that naturally replenish the beaches and the significant development of anthropisation of the coastal strip and the hinterland, will not cease completely with both hard and soft protection measures. All works require maintenance after completion, especially recharge measures, for which compensation for volumes lost over time must be cyclically planned. Without prejudice to the benefit of resorting to artificial beach recharge solutions, however, it should be noted that there are objective limitations in finding large quantities of sediment from underwater quarries that would allow the recharging of shorelines at economically sustainable costs.

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3.3 Impacts and adaptation actions for tourism

Assessing the impacts of climate change on the tourism industry is very complex (Hein et al., 2009). Interest in studying the relationship between climate and weather on the one hand and tourism on the other began around the 1950s (Scott et al., 2006). Until relatively recently, climate was considered a more or less stable feature of tourist destinations. It was assumed that the latter could not explain long-term trends in tourism demand (Hein et al., 2009). Climate change projections produced by the Intergovernmental Panel on Climate Change (IPCC) have led to a renewed interest in the relationship between climate and the tourism sector (Becken, 2013).

The climate of a tourist destination influences tourists' choices. In a scenario where the climate changes, it is possible that there will be positive or negative changes in tourism demand (NCCAP, 2022). Today, the tourism industry is called upon to predict the possible consequences (positive or negative) of climate change on the future tourism demand of a given destination (Bigano et al., 2006), in view of identifying business opportunities and investment or adaptation actions in the medium and long term (NCCAP, 2022).

On a global level, studies and assessments of the possible effects of climate change on tourism demand are being conducted in numerous tourist destinations. Research on the topic has only recently begun to appear in the scientific literature, which is limited due to the uncertainties and complexities associated with the study of climate change and the complex nature of the factors (objective and subjective) governing tourism demand (Amelung et al., 2007; Seetanah et al.,2019).

Literature suggests that the impacts of climate change on tourism can vary in magnitude, depending on the location of the tourist destination and its readiness and adaptability to change (Berrittella et al., 2006; NCCAP, 2022). Climate change may lead to opportunities for tourism development in seasons of low attendance due to a climate that becomes more agreeable. In other cases, climate change and related weather patterns may be a disadvantage affecting tourists' choices and the attractiveness of the tourist destination (Scheraga et al., 1998).

In order to highlight all possible links between climate change and tourism, an in-depth analysis of the tourism sector in Apulia and the Adriatic coast was initially conducted. Having defined the current tourism scenario, any possible relationship between climate change and tourism was then evaluated. Through the consultation of accredited bibliographic sources, the main expected impacts on the tourism sector were identified and classified, with exclusive reference to Apulia's Adriatic coastal tourism.

The collected information on impacts thus formed the knowledge base on which the subsequent analysis of climate change adaptation actions was structured.

Surveys carried out on the tourism sector indicate how the latter is also affected by climate change-induced effects on other entities, directly and indirectly related to tourism. This means that adaptation to climate change involves many different stakeholders, which may include public and private entities, tour operators and related services (transport, rescue, health, organisational), as well as individual residents and tourists.

As with the impact analysis, the definition of adaptation actions was based on an in-depth literature survey followed by a selection of the most suitable adaptation actions for the characteristics of the tourism sector on the Apulian Adriatic coast, distinguishing them for the main effects identified.

3.3.1 Analysis of the current scenario for the industry

Tourism is one of the most important economic sectors in the Apulia region. In 2022, the recovery of the tourism sector in Apulia, following the pandemic period, induced significant economic growth in the regional service and transport sectors, contributing to an increase in employment in the sector (Bank of Italy, 2022).

The financial importance of the tourism sector in regional GDP has gradually increased over the years. Data collected by the Regional Tourism Agency 'Pugliapromozione' and processed by IPRES (Istituto Pugliese di Ricerche Economiche e Sociali - Apulian Institute of Economic and Social Research), show that in 2006 tourism accounted for 3.4% of Apulia's GDP. In 2019, before the pandemic, the contribution of tourism to the regional GDP stood at 8.4%, and in 2021 at 6.9% (Pugliapromozione, 2021).

The data collected and processed by the Regional Tourism Agency 'Pugliapromozione', through the numerous annual reports it produces, also enable an overview of the distinctive features of Apulia's tourism demand and supply, which show:

1) **Steady growth in tourist arrivals and stays**
   From 1998 to 2019 the number of tourist arrivals and stays in Apulia grew steadily (Figure 3.3.1), with the exception of the Covid two-year period (2020-2021). "Arrivals", i.e. the number of customers, Italian or foreign, hosted in accommodation establishments (hotels or ancillary establishments), provide an indication of the popularity and tourist capacity of a given tourist location. The "stays", i.e. the number of nights spent by customers in accommodation establishments (hotels or ancillary establishments), provide an assessment of the tourist resources and tourist markets on which the destination is based, i.e. overall tourist satisfaction. In the summer of 2022, tourist arrivals and stays reached and exceeded the values recorded in 2019 as of June 2022. It should be noted that the growth of the Apulian tourism sector has undoubtedly benefited from the effects caused by tourism planning in Apulia, the first region in Italy to have a Regional Tourism Development Plan, called 'Puglia365'.

Puglia365 is a business plan that showed the vision and path towards which the development of the tourism sector in Puglia, in the period 2016-2025, was chosen, through the implementation of three strategies: deseasonalization of tourist flows, tourism promotion, and differentiation and improvement of the quality of the tourism offer.

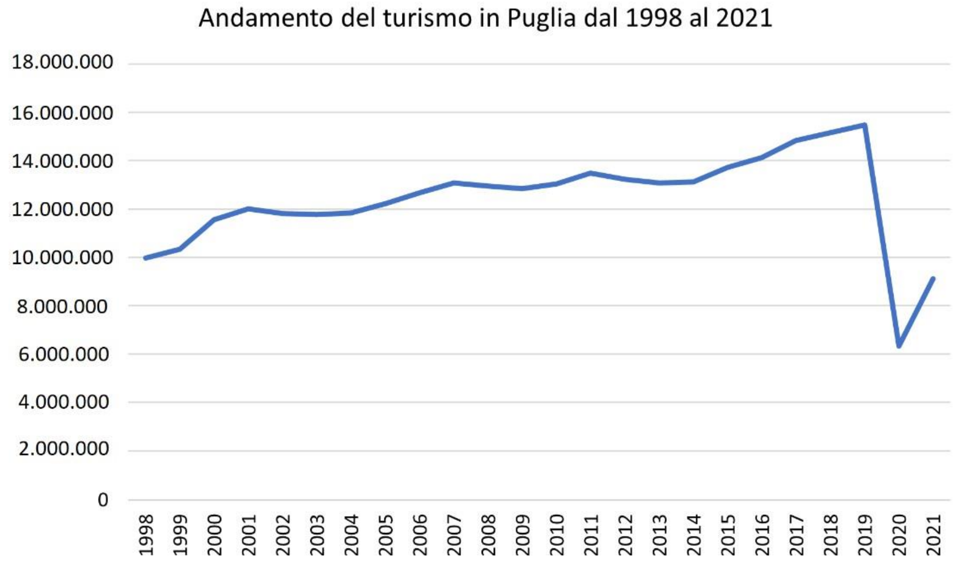

Figure 3.3.1. Tourism trends in Apulia Region from 1998 to 2021 (Data developed by Pugliapromozione).

2) **Good recovery capacity in the sector**
   Data on tourism trends for 2022 confirm the full recovery and further growth of the sector compared to the period before the COVID-19 pandemic (2020-2021).

3) **High seasonality of tourism demand**

   The monthly trend of tourist arrivals and presences in Apulia, monitored by the SPOT system (Sistema Puglia per l'Osservatorio Turistico), records higher values in summer (Figures 3.3.2). Seasonality has always characterised Apulia's tourist demand, an aspect that the Pugliapromozione data confirms for 2022 as well.

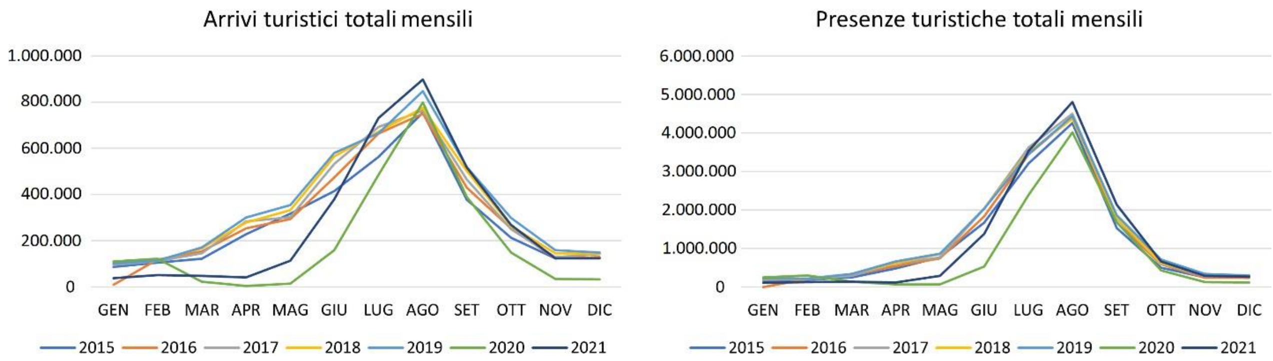

Figure 3.3.2. Total monthly arrivals and presences from 2015 to 2021 in Apulia Region (Data developed by Pugliapromozione).

Analysing the percentage growth trends of total seasonal tourist arrivals and stays between 2015 and 2019 (Table 3.3.1), it can be seen that the number of arrivals and stays grew more in the autumn (September - November) and spring (March - May) periods, and less for the winter (December - February) and summer (June - August) periods. These results show the early effects of the tourism deseasonalisation strategy pursued by the region, with a greater redistribution of tourist flows and an increase in the number of tourist stays throughout the year. However, summer tourism continues to record the highest number of total arrivals and stays, an aspect that greatly influences the regional tourism offer.

	Arrivals 2015	Arrivals 2019	Variation % Arrivals 2015-2019	Presences 2015	Presences 2019	Variation % Presences 2015-2019
WINTER	320.950	364.530	+14%	604.400	740.850	+23%
SPRING	667.897	823.996	+23%	1.499.785	1.865.321	+24%
SUMMER	1.731.814	2.093.056	+21%	9.138.969	9.916.396	+9%
AUTUMN	714.178	976.726	+37%	2.282.248	2.917.730	+28%

Table 3.3.2 Percentual variation of regional tourist arrivals and presences in the reference period 2015-2019.

4) Local and national tourism market

The Apulian tourist market has always been predominantly open to a local and national component of tourists (Figures 3.3.3). International tourist arrivals and stays covered 28% of the total arrivals recorded in Apulia in 2019, a Figures that decreased to 18.2% in 2021. In the Italian tourist market, Apulia competes with several regions with a high tourist potential, such as Veneto and Emilia-Romagna along the Adriatic, in which international tourist flows are more consolidated. The importance of the international tourist flow is due to the greater contribution made by these flows to seasonal adjustment, especially in the spring and autumn months. International tourists in Apulia are mainly from Europe, with France and Germany as the leading countries of origin of tourists, followed by central and northern European countries. Outside Europe, the Apulia tourist market is mainly open to the United States, followed by Canada and Israel. Less important, however, are flows from Asia, Africa, Oceania and South America.

At a provincial level, the foreign tourism specialisation index (the ratio between the weight of foreign tourist stays in the province and the weight of foreign stays in Italy, both expressed in %) takes values below 1 in every Apulian province, denoting a low specialisation in international tourism in all Apulian provinces compared to Italy. The province of Lecce, characterised by an index of 0.9, stands out from the other Apulian provinces, thanks to the presence of renowned seaside resorts that are in high demand by both the national and international tourist market (Unioncamere Puglia, 2022).

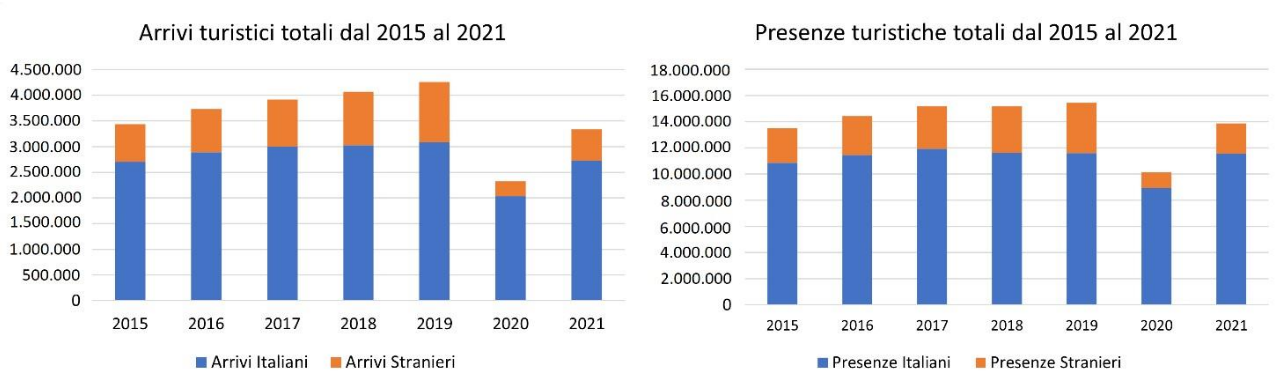

Figure 3.3.3. Total tourist arrivals and presences for Italians and foreigners in Apulia, from 2015 to 2021 (Data developed by Pugliapromozione).

5) Good differentiation of regional tourism supply

It is possible to classify Apulia's tourist offer considering three key elements: attractions, services (accommodation, catering and leisure) and accessibility (or ease with which one can travel to the destination). A list of attractions that are of interest to tourists, whether natural or man-made, can be found on the official tourism website 'viaggiareinpuglia.it', where the main tourist attractions in Apulia are classified by theme:

- **Arts and culture -** including art cities, UNESCO sites, museums, architectural elements and local crafts;
- **Tradition and spirituality** - with reference to cultural events, patronal festivals and events of local tradition;
- **Nature, sports and wellness** - with respect to the region's natural areas and sites for sports, wellness and spa activities;
- **Oenogastronomy** - includes the multitude of local food and wine products and their production areas, agri-museums and farms;

- **Sea-the** region's most important attraction, includes marine protected areas, beaches, and the landing and mooring points scattered along the coast.

Regional tourism themes contribute greatly to the diversification of tourism offerings and bring numerous benefits in terms of seasonal adjustment and widespread development. As reported in the "Puglia365" Plan, diversification also contributes to increasing the tourism sector's adaptive capacity and resilience. The "sea" theme is the most popular tourism theme, with a great force of attraction, an aspect found in the highest values of tourist arrivals and stays in coastal resorts. The development and diversification of regional tourism supply remain viable goals.

In terms of hospitality, there were more than 35,000 tourism enterprises registered in Apulia in 2021 and just over 142,000 employees, accounting for 5.4 per cent of the national total (Unioncamere Puglia, 2022).

Tourism catering establishments account for 64 percent of the regional tourism supply chain. This is followed by accommodation enterprises (mainly of the non-hotel type), which make up 12.4% of the tourism supply chain, enterprises related to cultural and recreational activities with 12.1%, transport enterprises with 6.5% and travel agencies and other services for the remaining 5%. In terms of accessibility, the regional railway network is made up of four railway lines that cross a large part of the regional territory. The main roads in Apulia are the A14 motorway, State Road 16, which crosses the entire region, State Road 97 and State Road 172. Of particular strategic importance are the regional ports and airports, which are the main gateways for international tourists to the regional tourism market. Apulia's main ports, which are open to passenger transport and the docking of cruise ships, are located in Bari and Brindisi, where the major regional airports are also located. The Tremiti Islands are reachable by ferry or helicopter.

6) **High values of tourism pressure in coastal resorts**

Data on municipal tourism trends show a greater presence of tourists in coastal localities, with higher tourist pressure indices (number of presences/inhabitants resident), compared to inland localities, particularly for the smaller coastal municipalities during the summer period. The decongestion of tourist flows from the coast to the hinterland is one of the priorities of the "Puglia365" tourism development plan, through the promotion and evolution of tourist consumption and of new alternatives to the sea.

Tourism on the Adriatic coast plays a major role in the Apulian tourism market. In 2021, about 60 percent of total regional tourist arrivals and stays were recorded in Adriatic locations (Figures 3.3.4). Apulia's top 15 tourist destinations include 11 localities with stretches of the Adriatic coastline: Vieste (FG), Peschici (FG), Bari (BA), Otranto (LE), Lecce (LE), Fasano (BR), Melendugno (LE), Carovigno (BR), Ostuni (BR), Monopoli (BA) and Rodi Garganico (FG).

The importance of the Adriatic coast in the regional tourism picture is linked to its rich tourist offerings. In terms of infrastructure, the presence of the main regional civil ports and airports along the Adriatic coast is worth mentioning. In terms of attractions, the Adriatic itinerary offers numerous valuable natural resources such as, for example, the Gargano National Park and coastal lagoons, the Tremiti Islands, Torre Guaceto and the Cesine. Anthropic attractions are represented by numerous coastal villages and towns and the rich historical and artistic heritage they preserve. Lastly, in terms of hospitality and services, there are many fine examples of accommodation and tourist facilities that are also internationally renowned.

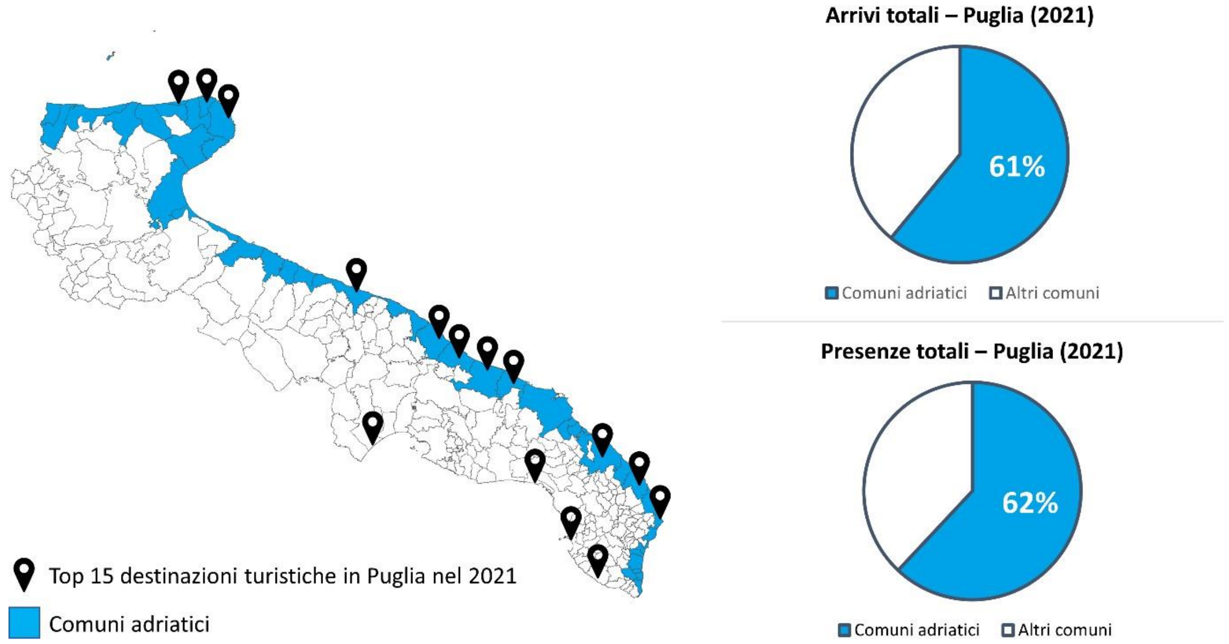

Figure 3.3.4. Top 15 Apulian tourism destinations in 2021 and total number of municipality arrivals and presences. Data: Adriatic municipalities and other municipalities.

3.3.2 Analysis of expected impacts

As stated in the National Climate Change Adaptation Plan (NCCAP 2022), the impacts of climate change on tourism fall into two categories:

- **A - direct impacts** cause changes in the flow pattern typical of a tourist destination;
- **B - indirect impacts** act by inducing changes in the attractiveness of the tourist destination, consequently influencing tourist arrivals and stays.

Direct impacts are related to the profile of tourists, their motivations for travelling, their ability to travel, and their subjective perception and evaluation of the tourist destination and the tourist goods and services on offer (IPCC, 2014). The direct effect of climate change on tourism leads to an adjustment of the spatial and temporal pattern of tourism demand (Rosselló-Nadal, 2014), in which the perceived climate in the various tourist destinations plays a key role in influencing tourists' choices. Variations in the number of tourist arrivals and presences, positive or negative reviews, and changes in the spatial distribution of tourist flows are some of the effects induced by climate change on tourism market values (Arabadzhyan et al., 2020). A full understanding of the direct impacts induced by climate change on tourism requires considering the intensity of climate change, not only in the destination under consideration but also in alternative destinations, including the countries of origin of each tourist (NCCAP, 2022).

The latter plays a key role, particularly in the international tourist movement for which a shift of travel destinations towards higher latitudes and altitudes is expected, whereby tourists from more temperate climates will spend more and more time in their home countries (NCCAP, 2022).

Indirect impacts derive from a series of modifications induced by climate change on the environmental, economic, and social elements of the tourist destination. The type of experience tourists have at their holiday destination is influenced by tourist goods and services purchased by tourists (Seddighi et al., 2002), the quantity and quality of which may be affected by indirect climate impacts. The attractiveness of the territory and the tourist destination can be helped or hindered by the effects of climate change (Arabadzhyan et al., 2020), with subsequent effects on tourists' holiday choices and the competitiveness of the destination. In addition, indirect impacts take on different connotations depending on the type of tourism activity considered. Tourist activities such as scuba diving or hiking in the woods can experience profoundly different indirect climate impacts, related, for example, to the different environmental component being considered, marine ecosystem in the former case and terrestrial ecosystem in the latter (Gourabi et al., 2012).

A - The direct impacts on tourism

The change in the number of tourist arrivals and stays on an annual and seasonal basis (Koenig et al., 2010) emerges as the exclusive direct impact of climate change on tourism in any given tourist destination.

Climate is a factor that greatly influences tourists' travel choices and preferences, capable of either favouring or detracting from the tourist experience enjoyed by travellers. Many recreational activities are related to the climate component. Beach tourism, the flagship product of Apulia's tourism offerings, is not exempt from the effects related to climate change.

For Apulia, climate change is expected to make the regional climate warmer than it is today, especially during the summer season, the duration of which may increase by 2050. An average increase in summer days of 13.7 days/year or 14.6 days/year is expected, depending on the emission scenario considered (RCP 4.5 in the first case, RCP 8.5 in the second).

Milder temperatures in winter, spring and autumn may benefit tourism (Scheraga et al., 1998) regionally by contributing to the deseasonalisation of tourism, with a greater redistribution of tourist flows throughout the year.

The increase in maximum summer temperatures may, on the other hand, lead to potential declines in the number of tourists in Apulia, making it less comfortable for holidaymakers to stay in holiday areas. High temperatures, linked to more intense and persistent heat waves in the Mediterranean area (Hooyberghs et al, 2017), could make the pursuit of many tourist activities in the open environment (terrestrial or marine) unsustainable, an aspect that may directly affect travel behaviour. More intense and frequent extreme weather events can also directly affect tourism demand.

Rising temperatures will affect not only Apulia but also other competitive tourist destinations (Koenig et al., 2010), both domestic and international.

This can have a negative or positive impact on tourism demand in Apulia, depending on the effects that climate change has on other tourist destinations. In general, climatic conditions, favourable to tourism, are expected to improve in central and northern Europe (Scott et al., 2012). For the countries in the Mediterranean basin, the progressive rise in temperatures, combined with the other effects of climate change (such as the rise in sea level), may adversely affect the tourist trade (El-Masry et al., 2021).

Tourism in Apulia is still strongly seasonal in character and with a tourist offer subordinated to the 'sea' product, it is more exposed to the direct effects of climate change.

To date, however, it has not been possible to state or prove that climate change is having any effect, either positive or negative, on the Apulian tourist trade. The lack of long-term series of data on regional tourism flows means that it is not possible to fully assess the effects of a changing climate on the number of tourist arrivals and presences recorded in regional accommodation facilities.

The monitoring of tourist flows therefore becomes crucial, not only to continue to guide effective planning of the sector, but also to correctly and promptly highlight any links between climate change and tourism at a local level, while allowing for the adaptation and proposal of specific, more effective adaptation strategies.

B - The indirect impacts on tourism

The indirect impacts of climate change on tourism are mainly due to climate-induced changes on the elements that shape a tourist destination (NCCP, 2022), such as attractive resources, services, tourist facilities and the local transport system (Scott & Lemieux, 2010).

Tourism is a cross-cutting economic sector, which by its nature has links with many other sectors and supply chains and is therefore susceptible to the effects that climate change has on these sectors and supply chains.

On a scientific level, the study of indirect impacts on tourism has been tackled using a multitude of different approaches. In this analysis, a series of phenomena were identified that already indirectly impact the tourism sector of the Apulian Adriatic coast, positively or negatively affecting the elements that shape a tourist destination (tourist attractions, tourist services and transport network).

The selected impacts are induced by climate-related events that, based on the scientific literature, are expected to increase in frequency and/or intensity due to climate change. Six main indirect impacts have been identified, which are capable of conditioning the tourist appeal and competitiveness of the Apulian Adriatic coast (Table 3.3.2).

	Impact	Impacted element of the tourist destination*
	Increase in forest fires in tourist areas	Tourist attractions
		Tourist services
		Local Transport Network
	Increase of alien and invasive species in land and marine tourist use areas	Tourist attractions
		Tourist services
	Thermal stress and health hazards to tourists and practitioners	Tourist attractions
		Tourist services
	Decreasing domestic water for tourism industry and increasing energy consumption	Tourist services
	Damage from extreme weather events to accommodation, service, transportation and cultural and agricultural heritage infrastructure and facilities	Tourist attractions
		Tourist services
		Local Transport Network
	Coastal erosion and reduced beach availability	Tourist attractions
		Tourist services
		Local Transport Network

Table 3.3.2. Indirect impacts due to climate change for the hospitality sector on the Apulian Adriatic coast.

* **Tourist attractions**: Elements of the area (natural or anthropic), able to attract tourists, such as natural parks, monuments, beaches, tourist ports, museums, amusement parks, theatres, fairs, festivals, shopping centres, lighthouses, commercial and state-owned tourist areas;

* **Tourist services**: It includes facilities/areas of tourist accommodation (hotel and complementary facilities) and tourist enjoyment (restaurants, tourist service areas, bathing establishments, agritourisms, amusement and adventure parks, souvenir or other items stores, bars, travel agencies, info points, etc.). Also belonging to this category are complementary services from which tourists and business operators can also benefit (health care, rescue activities, security and emergency management, electricity and drinking water supply, urban green maintenance, etc.);

* **Local Transport Network:** Refers to the local transport network (local or public) servicing tourist areas.

The impacts listed in Table 3.3.2 are described below.

B.1 - Increase in forest fires in tourist areas.

The average increase in temperatures and reduction in precipitation, linked to climate change, will cause increased levels of drought and higher levels of exposure of forests to fire risk (Michetti & Pinar, 2018; Mukherjee et al., 2018). Adverse weather conditions and increased biomass accumulation create the basic conditions for the ignition of increasingly large and intense forest fires (Flannigan et al., 2009; Terrén & Cardil, 2016).

The length of the fire season in different areas of the world, particularly in the Mediterranean region, is expected to increase due to climate change (Giannakopoulos at al., 2009; García-Ruiz et al., 2011; IPCC, 2014). Warmer and drier spring and autumn seasons will make vegetation drier and more flammable which, together with increasingly longer summer seasons, will have a great impact on the vulnerability of forests to fires (Marques et al., 2011). The risk will be greatest in areas that are already particularly exposed to the phenomenon.

Tourism is particularly susceptible to the increasing risk of forest fires (Arabadzhyan et al., 2020; Otrachshenko et al., 2021), not only in relation to the physical damage to forests (an attractive feature of many tourist destinations), but also because of the serious increase in air pollution and the danger such events pose to people's lives (Shaposhnikov et al., 2014). The study by Otrachshenko & Nunes (2021) confirms how forest fires negatively affect tourist demand, with a reduction in the total number of tourist arrivals. Forest fires affect not only 'forest' tourists, but also those who use forest products and services or benefit from the forest system for various activities (including sports, camping, and hiking) (Ostrachshenko et al., 2021).

In Apulia it is well known that urban-forest interface areas are particularly exposed to fire risk due to the higher probability of ignition (Elia et al., 2014). Along the Apulian Adriatic coast, there are numerous interface areas exposed to the problem, represented by forest and natural protected terrestrial areas, coastal reforestations, Mediterranean thickets and scrublands close to urban areas and relevant to tourism (Elia et al., 2018). Most of the fires recorded are linked to careless forest management, mainly within Mediterranean scrubland near tourist resorts and areas of tourist use (Elia et al., 2014). In proper forest management, seasonal population fluctuations need to be considered, especially in landscapes and territories where tourist demand is particularly high (Lafortezza et al., 2015). Concentrating fuel management interventions in these places would reduce the incidence of the phenomenon due, very often, to incorrect behaviour of residents and tourists (Leone et al., 2002).

Although climate change-related increases in forest fires may affect tourism supply and demand, research on this subject is still limited and needs further investigation (Arabadzhyan et al., 2020).

B.2 - Increase of alien and invasive species in land and marine tourist use areas

Alien or non-native species (AS), referred to in more general terms as NIS (Non-indigenous Species), are organisms introduced outside their natural distributional range (past or present) and outside their natural dispersal potential. Invasive alien species (IAS) are defined as alien species whose introduction or spread poses a threat to biodiversity, may cause harm to human health or have serious socioeconomic consequences (MASE, 2009). Their presence in a given region may be due to intentional or unintentional introduction by humans, or for different causes, e.g. related to international tourist activity (Occhipinti-Ambrogi, 2007; Hall, 2019; de Virgilio, 2021).

Climate change is among the most influential factors affecting the distribution, survival and spread of invasive species (MASE, 2009). Increasingly exceptional developments of alien species have been observed in many regions of the world (Occhipinti-Ambrogi, 2007), particularly in the Mediterranean area (Corrales et al., 2018), with significant biodiversity losses in the eastern basin (Albano et al. 2021).

Climate change can promote biological invasion processes by increasing, for example, the ability of some NIS species to invade new regions, compromising the conservation of biodiversity and natural resources (Katsanevakis, 2014). The growing use of nitrogenous fertilisers, the spread of pollutants and the degradation and loss of habitats caused by human activities can also, together with climate change, influence the distribution of species and resource dynamics in both terrestrial and aquatic ecosystems with the consequent interaction with biological invasions (Occhipinti-Ambrogi & Galil 2010).

In the Mediterranean Sea, climate change favours, mainly with rising temperatures, a massive spread of NIS species, including plants (Gritti et al., 2005), insects (Harvey et al., 2022), marine plant and animal species, both invertebrates and vertebrates (Occhipinti-Ambrogi, 2007). Benthic and pelagic NIS algae (phytoplankton) are widespread and often cause blooms and HAB (Harmful Algal Bloom) incidences (Zingone, 2009). There are numerous consequences of these invasions, not only ecological, but also economic and sanitary (Perrings, 2002; Molnar et al., 2008; Vilà et al., 2010).

Impacts on tourism caused by invasive species can be positive or negative.

Possible benefits would come from the creation of new habitats with attractive and recreational value (Liquete et al., 2013), inhabited by new species of interest to tourists.

However, there are numerous negative aspects. The presence of alien species can lead to the loss of numerous native species and entire habitats (IPCC, 2023). Numerous alien macroalgae exert this type of impact, such as the Caulerpa racemosa var. cylindracea, which has arrived in the Mediterranean from Australia, as well as on the Apulian coasts (Gravili et al., 2010), where it competes with other benthic organisms and with the phanerogamous Posidonia oceanica, a species characteristic of Mediterranean marine habitats.

Aesthetic impacts caused by the proliferation and accumulation on beaches of algae and/or jellyfish are also reported (Arabadzhyan et al., 2020; NCCP, 2022; Tsirintanis et al., 2022).

Numerous invasive alien species can cause problems for human health by causing injuries, allergies and transmitting new diseases. For example, the nomadic Rhopilema, which has reached the

Mediterranean Sea through the Suez Canal, creates several problems for both fishing and tourism as it is a highly urticant species that is widespread especially along the coasts where it often tends to beach. Soft reefs can favour the larval settlement of gelatinous organisms that have the benthic polyp phase. Jellyfish also appear to be more resistant to anoxic conditions (Richardson et al., 2009), often caused by coastal organic discharges and exacerbated by warming waters. Some alien fish found in Italian seas, such as the scorpion fish (Pterois volitans) and rabbit fish (Sigarus rivulatus and Sigarus luridus), are very toxic or harmful to the safety of swimmers and divers (Katsanevakis et al., 2014).

Toxic species include Ostreopsis ovata, which, as a result of its intense proliferation, known as 'bloom', causes numerous health problems for bathers (dyspnoea, colds, fever), as occurred in several areas of Italy in the summers of 2005 and 2006 (Occhipinti-Ambrogi & Galil, 2010; Tichadou et al., 2010). Although it is believed that high seawater temperatures favour the flowering of O. ovata, there is still a need for further studies in the literature to confirm this. However, since it is a benthic algae, its spread can be encouraged by soft barriers.

Even in terrestrial and urban ecosystems, the spread of alien species linked to climate change can contribute to the sense of unease felt by residents and tourists. Changing climatic conditions can affect the survival, fecundity, development and dispersal of both native species (Roques, 2010) and alien species of insects, arachnids and small invertebrates, resulting in possible infestations (Battisti & Larsson, 2015).

The presence of alien insects in tourist areas can lead to damage of aesthetic significance, e.g. on the attractiveness and plant decorations of parks and gardens, monumental trees and natural green areas. Other species such as the elm bug (Arocatus melanocephalus), although not dangerous to humans, emits an unpleasant odour if disturbed; it is a particularly invasive species (Nicoli Aldini & Peretti, 2002) that for climatic reasons tends to occupy domestic dwellings to escape the high summer temperatures (Dutto & Caparezza, 2011).

Other species are linked to the spread of new diseases. The role played by various mosquito species in the transmission of viruses and diseases is well known. Climate change (Brugueras et al., 2020), together with other factors, may favour the spread and migration of new species by facilitating the transmission of new diseases to previously unexposed areas (Bartlow et al., 2019). In recent years, cases of Dengue fever (a viral disease whose transmission is due to the Aedes aegypti mosquito) have been reported in several Mediterranean countries, such as Croatia, France, Greece, Italy, Malta, Portugal and Spain. During the hot summer of 2017, outbreaks of Chikungunya (another viral disease with carriers being mosquitoes of the genus Aedes) were reported in France and Italy (Cramer et al., 2018).

Numerous marine alien species are now well established along the Apulian coasts (Gravili et al., 2010), however, further studies and in-depth investigations, as with terrestrial invasive species, are still needed to better define problems and the consequences on tourism (Arabadzhyan et al., 2020).

B.3 - Thermal stress and health hazards to tourists and practitioners

Rising temperatures and increasingly frequent heat waves caused by climate change expose more vulnerable residents, tourists, and workers to increased health risks (IPCC, 2023), particularly during the summer period.

Exposure to high temperatures leads to an increase in cardiovascular problems (Telesca et al., 2023) and a more general increase in the risk of hospitalisation (Linares et al., 2020; Astone et al., 2023). Temperature, however, is not the only climatic quantity that affects thermal risk.

High air humidity, induced by increased evaporation of water, can cause the body's thermoregulation system to perform poorly (Ahima 2020). Several factors contribute to people's susceptibility to high temperatures (Wolf et al., 2013) such as age, individual behaviour, air pollution and the extent and density of urban areas (Noro et al., 2015). In the Mediterranean area, in densely urbanised cities such as Bari (Martinelli et al., 2020), the presence of 'heat islands' favours the local increase in temperatures with negative effects on the energy performance of buildings (Battista et al., 2020), as well as an increase in the sense of discomfort and health risks for the most fragile individuals (Di Rienzi et al., 2006).

In Apulia, as in the entire Mediterranean area, climate projections depict a progressive increase in average and maximum temperatures, particularly during the summer season, which is expected to increase in duration, with a progressive increase in the number of summer days (indicator SU95p). In coastal regions, the rise in land and sea temperatures, during the day as well as at night, together with the attainment of high levels of relative humidity (NCCP, 2022), will lead to very uncomfortable conditions for the local population as well as for foreigners and tourists (Giannakopoulos et al., 2011).

The consequences of thermal stress are not only limited to the health field but are also financial. Many manufacturing sectors can be affected by the impacts produced by high temperatures (Gomez-Martin et al., 2014). In terms of tourism, excessive heat can alter the normal behaviour of tourists by influencing their choices (Gössling et al., 2006), the way they travel, the type of activities they wish to engage in (Cavallaro et al., 2017; Gómez-Martín et al., 2014) and the type of facilities in which they stay (Gomez-Martin et al., 2014), generating changes in both the supply and demand for tourism within destinations. Excessively high temperatures are a deterrent to tourism and a factor that may discourage travel choices to specific destinations and attractions. Among tourists, the risks associated with thermal stress may affect children and frail and/or elderly people more significantly (Basu, 2009; Gómez-Martín et al., 2014).

On a local level, an increase in the number of hospital admissions may occur (Toloo et al., 2015), which is more troublesome for smaller tourist resorts. In addition, the comfort of tourists may be indirectly affected by a decrease in the availability of water (see discussion of the specific impact). Future research on this topic should better investigate the consequences of urban growth and climate change on urban heat islands and heat stress. Considering individual risk factors may underestimate the urban temperatures that can be reached, thus hindering adaptation (Chapman et al., 2017).

B.4 - Decreasing domestic water for tourism industry and increasing energy consumption

Climate change can have an effect on the quality and quantity of services provided by facilities and infrastructure, e.g. through a decrease in the availability of drinking water for civil use (Gössling et al., 2012). This is of great importance especially for countries and regions that already suffer from water scarcity.

By 2050, average temperatures in Apulia are expected to increase and rainfall to decrease across the whole territory, in line with the projections made for southern Italy in the 2022 NCCP. The decrease in drinking water will become a problem for Apulia and the whole of southern Italy (De Luca et al., 2022) that will need more attention.

For the Mediterranean region, research explores how the decrease in rainfall will affect the availability of drinking water (Philandras et al., 2011), investigating the costs and problems to which specific economic sectors will be exposed, such as tourism (Martínez-Ibarra, 2014).

Lack of potable water can seriously damage the competitiveness of a tourist destination. Not all types of tourism depend on water in the same way and intensity. Coastal tourism, predominantly in the summer, requires a lot of water for sanitation, catering and recreational activities. Water scarcity in these destinations may affect tourists in a more pronounced way, due to fewer water-based recreational activities and water supply disruptions in hotels (Arabadzhyan et al., 2020).

In a European study on the use of water by the tourism sector (EUROSTAT, 2009), a number of specific problems emerge, two of which are particularly relevant: the peak demand during summer droughts and the concentration of tourist destinations in coastal areas with very scarce water resources. It is clear how inefficient management of water resources can increase the chances of water supply crises in tourist destinations, especially in unfavourable climatic situations.

In association with climate change, there are also changes in energy consumption levels. Climate change may enhance or worsen the thermal comfort of a given region and this may be associated with increases or decreases in the consumption of certain energy resources (electricity or gas) (Giannakopoulos et al., 2a011).

Increasing summer maximum temperatures may result in higher energy expenditure for cooling accommodation (Giannakopoulos et al., 2009), which for Southern Europe may exceed the decrease in winter heating needs, leading to higher annual energy costs (Pilli-Sihvola et al., 2010; Zachariadis, 2010). The increase in energy consumption linked to climate change and an increase in the number of tourist arrivals and stays, especially for highly seasonal tourism, can put great pressure on the energy distribution system. This aspect becomes more significant for more isolated and smaller tourist resorts, where there is an outdated energy infrastructure or limited production capacity.

B.5 - Damage from extreme weather events to accommodation, service, transportation and cultural and agricultural heritage infrastructure and facilities

Climate change is recognised as a factor that can greatly influence the frequency and intensity of extreme climate events (Trenberth et al., 2015; IPCC, 2023) in relation to the increase in minimum and maximum temperatures and other climate indicators such as the 95th percentile of precipitation (P95) or the number of days with intense precipitation (R20). Through these climate indicators, consequences with immediate effects such as heavy rainfall and flooding are predicted (IEEP, 2006).

The results of the climate projections described in Chapter 2 indicate for Apulia a low increase in the number of days of intense precipitation (R20) and an increasing trend in the rainfall intensity index (P95). It should be noted that the Mediterranean area is recognised as being particularly vulnerable to the effects of climate change with an expected increase in extreme weather events in terms of frequency and intensity (Mastronuzzi & Sansò, 2004).

The Mediterranean coasts are also expected to be particularly exposed to these effects due to the presence of numerous structures and infrastructures (including tourism) near the coastline (Ronchi, 2019; El-Masry et al., 2021).

Apulia has always been prone to extreme weather events such as tornadoes and sea storms along several stretches of the coast (Mastronuzzi & Sansò, 2000; Gianfreda et al., 2001; De Martini et al., 2003; Mastronuzzi and Sansò, 2004; Mastronuzzi et al., 2007). In the past, these events did not cause serious damage because the coastal areas were almost completely uninhabited. The current coastal situation is, on the other hand, characterised by urban areas (of medium and high population density), ever-expanding tourist resorts, and roads and railroads which, if subject to flooding or other extreme events, suffer extensive damage with serious economic consequences (Martinotti, 2017). Another aspect to consider is the presence of numerous valuable assets, cultural sites and natural areas along the entire Adriatic coast (Antonioli et al., 2017).

At the level of individual structures and infrastructures, their deterioration over time (also driven by climatic factors) leads to an increase in their vulnerability to damage caused by extreme climate events (Arabadzhyan et al., 2020).

A possible acceleration of structural deterioration processes induced by climate change leads to increased risks and costs of maintenance and restoration of architectural and cultural heritage assets in particular (Sesana et al., 2020; Orr et al., 2021). Indeed, the damage caused by extreme climatic events to real estate and monumental heritage is of great importance in areas with a strong tourist trade.

The amount of damage is not solely attributable to the extreme weather event that caused it. The varying exposure and vulnerability of the structures to the extreme climatic event, the intactness of the affected buildings, the presence of people and tourists, the quality of the construction materials used, and the proximity of the structures to the sea or to areas prone to disruption, all have a great influence on the amount of damage incurred, leading to a greater or lesser degree of destruction.

B.6 - Coastal erosion and reduced beach availability

It is predicted that climate change and subsequent sea level rise may cause the coast to retreat inland (Hinkel et al., 2013; Arabadzhyan et al., 2020; Vousdoukas et al., 2020).

Residential use and service activities developed around numerous beaches around the world have greatly stimulated so-called 'sun' and 'sand' tourism (Aguilo et al., 2005; Sardá et al., 2009). The loss of the beach resource may lead to serious damage to beach tourism and to all tourism activities that take place on the coast, with economic losses for the sector (Rizzetto, 2020) and a reduction in the appeal of the tourist destination (Arabadzhyan et al., 2020). Low coasts are particularly prone to suffer such consequences (Delle Rose, 2015).

Future projections see the Apulian Adriatic coast at great risk of erosion. The planned retreats, considering the already limited widths of the average Adriatic beaches, could in some cases lead to the disappearance of some existing beaches. For more on the topic of coastal erosion in Apulia, see Section 3.2.

3.3.3 Adaptation actions

Analysis of the impacts of climate change on tourism on the Apulian Adriatic coast guided the selection of adaptation actions.

The proposed actions were evaluated and chosen on the basis of scientific documents and reliable bibliographic sources, experiences and projects that described their usefulness:

- reaping benefits from the expected impacts by stimulating tourism development;
- preventing the occurrence of the impacts themselves by acting on the triggering conditions;
- effectively managing the expected impacts in order to contain their negative effects.

The proposed actions were classified according to the specific impact they refer to, whether direct or indirect, and in the latter case the relevant indirect impact was specified.

A - Adaptation actions for direct impacts

The only direct impact induced by climate change on tourism is a change in the number of tourist arrivals and stays in the tourist destination (annual and seasonal).

The most important adaptation measures to manage and reduce the decline in tourist arrivals and stays related to climate change in Apulia include actions to diversify the tourist offer and deseasonalise flows. In accordance with the National Tourism Plan (TSP, 2017), the Apulia Region already pursues these actions, as indicated in the 'Puglia365' Strategic Tourism Plan. Tourism deseasonalisation could benefit from the gradual increase in temperatures during periods of low tourist influx, helping to increase the appeal of the Adriatic coastal areas in periods other than summer, favouring the growth and distribution of tourist flows throughout the year. At the same time, the diversification of tourism products (TSP, 2017) stimulates the creation of new industry segments that can attract and increase the share of tourists, including foreigners, visiting Apulia (Puglia365), acting synergistically with deseasonalisation.

The 2022 NCCP points out that, at the Italian provincial level, the change in tourist flows, caused by climate change, will not be uniform, but will be influenced by the different international and national popularity of the various tourist resorts. A proper adaptation strategy, through deseasonalisation and differentiation of the tourism offer, must aim at increasing the popularity levels of tourist destinations, stimulating the development of the sector and the promotion of high-quality tourism products, also through the training and information of operators in the sector on the issue of adaptation to climate change. Tourists could also benefit from specific measures that may include taking out insurance to manage climate risks (Hossein et al., 2015; NCCP, 2022).

Table 3.3.3 summarises the main actions that can be implemented.

The purpose of the actions proposed in Table 3.3.3 is to focus on improving and consolidating Apulia's tourism reputation, in the belief that by enhancing its tourism products it is possible to reduce the negative effects of the direct impacts associated with climate change.

Actions	Description	References
Seasonal adjustment of tourist flows	Encourage tourists to plan their holidays at times other than the traditional ones	PST, 2017 Puglia365 NCCAP, 2022
Diversification of tourism offer	Supplement or replace the more traditional tourism products (beach tourism) with other proposals that can be an attraction for tourists (wine and food tourism, sports, rural tourism)	PST, 2017 Puglia365 NCCAP, 2022
Study and monitoring of the effects of climate change on tourism flows	Detect and monitor the environmental, social and economic effects of climate change in the tourism destination and share the results	NCCAP, 2022
Training of tourism professionals on climate-sensitive hazards and possible impacts on the tourism industry	Scheduling of training courses on risks caused by climate change for those involved in the tourism sector	NCCAP, 2022
Promotion of insurance for climate risk management	Promoting the use of innovative insurance products to reduce damage related to extreme weather events	NCCAP, 2022

Table 3.3.3. Actions to adapt to the variation in the number of tourist arrivals and stays, on an annual and seasonal basis, in the tourist destination.

B - Adaptation actions for indirect impacts

B.1 - Increase in forest fires in tourist areas.

Combating the increase in forest fires begins with the prevention, management and maintenance of forested areas in compliance with the relevant laws and plans. In particular, areas with high tourist density require more attention, given their higher vulnerability to fire (Elia et al., 2014; Lafortezza et al., 2015).

Numerous prevention actions can be implemented, such as the management of necromass and waste in forest and interface areas, as regulated by Apulia Regional Law no. 38 of 12/12/2016 "Forest and interface fire fighting regulations." Awareness-raising campaigns and the promotion of appropriate behaviour for tourists and operators in the tourism sector, as well as more careful regulation of recreational activities carried out in the forest, offer greater guarantees of preventing fires from starting. These are activities carried out annually in Apulia by the Regional Agency for Irrigation and Forestry Activities (ARIF) and the Civil Defense.

Of considerable importance, including in facilitating rescue and firefighting operations, is the restoration or provision of escape routes through the adjustment and maintenance of forest roads, accompanied by appropriate signage. Studying the effects of climate change on forest fire risk can spur the formulation of new adaptation and mitigation actions (Flannigan et al., 2006).

Monitoring the areas most at risk can benefit from the adaptation and modernisation of control and supervision systems (Karali et al., 2023). The drafting, updating and implementation of forest management plans (at regional and municipal levels) is of great importance in preventing the outbreak of forest fires and planning rescue operations.

The set of proposed adaptation actions for fighting forest fires in tourist areas are listed in Table 3.3.4.

Actions	Description	References
Fire risk management in urban-forest interface and forested tourist areas	Drafting of management or intervention plans for urban-forest interface areas with a tourist trade and the introduction of forest fire protection systems (green belts, active and passive firebreaks, forest roads for main forest fire-fighting use, tracks, water supply points) and adaptation and renewal of equipment and means necessary for fire-fighting intervention and monitoring actions	Elia et al., 2014 Lafortezza et al., 2015 AIB Plan - 2022
Management and maintenance of forest roads and adaptation of road signs	Ensuring the intactness and good condition of forest roads to facilitate reconnaissance and active forest firefighting operations, also for the protection of tourists and local people	Ministerial Decree of 28/10/2021 "National Minimum Criteria on Forest Viability"
Awareness and information campaigns on forest fire risk and fire regulations	Awareness raising and information of local people and tourism stakeholders on fire regulations, general rules on lighting fires in the forest, escape routes and behaviours to be adopted in case of danger	Broad prescriptions and forest police - Apulia ARIF / Civil Defense Awareness Campaigns.
Waste and biomass management in the forest	Managing and combating the accumulation of necromass and litter in forest fire hazard areas and promoting behaviours to prevent the ignition of flammable material in the forest by tourists and operators	Life Project «Bioenergy & Fire Prev.»
Adaptation of the monitoring and warning system	Set up or enhance, where necessary, appropriate forest fire monitoring measures (including involving volunteers and tourism sector operators) and improve methods of communication and interpretation of fire risk bulletins for the benefit of the public and tourism sector operators in the most vulnerable areas	NCCAP, 2022 Karali et al., 2023

Table 3.3.4 Actions to adapt to increased forest fires in tourist areas.

B.2 - Spread of alien and invasive species in land and marine tourist use areas.

The spread of invasive alien species in natural and man-made areas is determined by many factors acting on vast spatial scales. At a local level, sectors such as tourism can tackle the problems linked to the presence of these species, first of all through campaigns to raise awareness of the phenomenon, as in the 'Attenti a quei 4' campaign implemented by ISPRA and CNR-Irbim to inform citizens, explain how to recognise and monitor the presence and distribution in Italian waters of four alien and toxic fish species, thanks also to reports from fishermen and divers.

Monitoring makes it possible to ascertain the levels of invasion, spread, and presence of certain alien and/or toxic species in certain settings, including tourist contexts. The collection of information in monitoring campaigns can also benefit from the possible involvement of Figures such as fishermen in the fishing tourism sector, divers, environmental excursion guides, etc. The sharing of information collected through monitoring, including through the creation of specific databases (Azzurro et al., 2022), can therefore facilitate awareness-raising activities, which are necessary for the promotion of appropriate behaviour and forms of management of the problems related to the phenomenon of biological invasions (MASE, 2009; Carotenuto et al., 2020), which are also useful for identifying possible opportunities to be exploited.

The set of proposed adaptation actions related to the spread of alien and invasive species in land and marine tourist use areas is listed in Table 3.3.5.

Actions	Description	References
Awareness campaigns on the spread of biological pests/dangerous organisms and promotion of appropriate management techniques	Encouraging the recognition of invasive/alien and dangerous species by the general public and tourism operators, and the spread and consolidation of public awareness about the need to adapt lifestyles to the possible consequences of climate change (negative or positive) on marine and terrestrial ecosystems (including fisheries, aquaculture and tourism sectors)	ISPRA & CNR-IRBIM "Attenti a quei 4" (Beware of those 4) campaign
Monitoring of alien, toxic, dangerous climate-sensitive species that may give rise to large-scale proliferations	Identifying the possible spatio-temporal trajectories of the spread of native and allochthonous pests and pathogens in relation to climate change and facilitating the communication of warning/attention messages for tourists and practitioners, including through the creation and sharing of databases or information web pages for the benefit of tourists and practitioners	Azzurro et al., 2022 "Ostreopsis ovata" monitoring - ARPA Puglia
Sustainable actions to contain invasive species	Control of insects/animals vectors of disease and nuisance in urban/lacustrine/woodland areas of tourist use. Drafting specific management plans for invasive alien species	Tricarico et al., 2019 Carotenuto et al., 2020 ADRIADAPT 2022

Table 3.3.5 Actions to adapt to the spread of alien and invasive species in land and marine tourist use areas.

B.3 - Thermal stress and health risks of tourists and workers in the tourism industry

Urban green infrastructure and appropriate building thermal insulation techniques are among the most effective and applied adaptation actions to reduce impacts related to thermal stress through reducing the urban heat island effect (Noro, 2015). Urban shading can be fostered not only by plants and urban green infrastructure (Lafortezza et al., 2009), but also through architectural solutions or elements of urban decoration, which can also act as tourist attractions in certain contexts.

Monitoring urban heat islands can provide valuable information that allows the most critical areas to be identified and subsequently inspire appropriate forms of urban management. For tourism, the information gained from the study of thermal risk in cities may suggest new and more effective solutions for managing the problem and forms of protection for tourists and tour operators, e.g. by adjusting shifts during the cooler parts of the day or improving the thermal comfort of tourist buildings and facilities (Hooybergh s et al., 2017).

The application of thermal stress adaptation solutions and strategies to protect tourists and residents can also generate a great deal of appreciation from travellers (Leòn et al., 2021), with a positive financial return for the sector.

The set of proposed adaptation actions for thermal stress and health risks to tourists and tourism workers are listed in Table 3.3.6.

Actions	Description	Bibliographical references
Heat island monitoring and management	Identification, monitoring and management of heat islands in urban areas and implementation of urban shading techniques or solutions to contain the extent of the problem for tourists and the local population	Lafortezza et al., 2015 NCCAP, 2022
Awareness-raising, information and promotion of appropriate forms of protection for exposed individuals	Development of an information system that facilitates the reporting of effects resulting from high temperatures on population health, well-being and safety (deaths, number of accesses to health care). Encourage awareness of the issue among tourists and practitioners through the promotion of appropriate behaviours	INAIL Strategy "Knowing the Thermal Stress Risk."
Thermal insulation and cooling techniques for accommodation facilities	Adoption of construction strategies and techniques that ensure thermal comfort and contribute to lower energy consumption	Hooybergh s et al., 2017 ADRIADAPT - "Improving thermal comfort in buildings."
Urban green infrastructure and urban shading solutions	Implementation of urban green infrastructure and development of urban green management guidelines for local governments	Lafortezza et al., 2009 NCCAP, 2022

Table 3.3.6 Actions to adapt to thermal stress and health risks of tourists and tourism workers.

B.4 - Decreasing domestic water for tourism industry and increasing energy consumption

Reducing consumption and sensible use of water sources are among the most common adaptation strategies applied to cope with drought-related problems.

Awareness campaigns, waste management and proper maintenance of the water distribution network are crucial for promoting sustainable water use in the tourism sector (FPA, 2021). In Apulia, the percentage ratio of total losses to the volume of water fed into the water supply stands at 45.6 percent (ISTAT, 2021), so reducing water losses becomes a key objective.

On the energy side, opportunities for renewable energy production need to be explored further in relation to projected climate change scenarios. Upgrading and maintaining the electricity distribution network can prevent overloads and imbalances in energy supply, particularly during the summer season, which is expected in Apulia to lengthen its annual course with increasingly high maximum temperatures. Consider also that summer is the peak season for tourism in Puglia, with more people connected to the network.

The set of proposed adaptation actions for decreasing domestic water for the tourism industry and increasing energy consumption is listed in Table 3.3.7.

Actions	Description	Bibliographical references
Training and promotion of sustainable water use, including through proper management of the distribution network	Dissemination of theoretical knowledge and practical information on the drought phenomenon through the development of a water-saving best practice sharing system involving tourists and practitioners	AQP - Sustainability Plan 2022/24
Renewable energy production systems	Installation of renewable energy production systems (e.g., solar panels) and energy storage systems to address the intermittent nature of renewable sources and increased variability related to climate change	Apulia Regional Environmental Energy Plan (P.E.A.R.)
Reduction of water and energy consumption	Adoption of measures and promotion of behaviour or good practices to optimise energy consumption in accommodation and tourist facilities, with the aim of containing the costs of lighting and/or heating of facilities during critical periods (hot summers, etc.) also with financial incentives	AQP - Water Saving Campaigns.

Table 3.3.7 Actions to adapt to the decrease in domestic water for the tourism industry and the increase in energy consumption.

B.5 - Adaptation actions for damage from extreme weather events to accommodation, service, transportation and cultural and agricultural heritage infrastructure and facilities

Understanding weather and climate phenomena that can cause damage is imperative for reducing possible hazards related to them. Setting up and updating weather warning systems and promoting appropriate emergency management behaviours are critical.

Adaptation should also be combined with other planning tools through the creation of specific urban adaptation plans that include sections dedicated to tourism and the specific effects that cultural and real estate assets may face (biological degradation, coastal erosion, debris flows, etc.) (Nicu & Fatorić, 2023). In urban adaptation plans, all knowledge related to hydrogeological risk must be systematised, and critical factors related to sewage and water drainage systems must be analysed, the design criteria of which should be reviewed for their adequacy to projected climate change scenarios.

The same applies to the local transport network and the main infrastructure and facilities serving urban, agricultural and coastal communities, which will have to be built in a climate-proof manner in order to adapt to future climate change (MIMS, 2022). Monitoring of building materials and proper maintenance of buildings and urban greenery contribute to adaptation (NCCP, 2022).

Where necessary, considering the increase in adverse weather conditions or potentially triggering flood events, current emergency and evacuation systems should be reviewed or updated.

The set of proposed adaptation actions for extreme weather event damage to accommodation, service, transportation, and cultural and agricultural heritage infrastructure and facilities is listed in Table 3.3.8.

Actions	Description	Bibliographical references
Adjustment of emergency management procedures on the road network	Structuring a network of mobility systems and alternative routes to provide tourists and business operators with assistance services in cases of weather emergencies (fires, storms, gales, tornadoes). Where necessary, review or reinforce current emergency and evacuation systems considering the increase in adverse weather conditions or potentially triggering flood events	NCCAP, 2022
Management and maintenance of urban greenery and review of design choices	Maintenance of urban greenery to prevent trees from falling on people or residential structures in urban and tourist areas in order to ensure safety	Law No. 10/2013 "Regulations for the development of urban green spaces"
Climate warning and promotion of appropriate actions to cope with hazards	Set up warning systems that act on two key elements: constant improvement of forecasting models and interpretative tools, and increasing community awareness of critical issues in their context, including through the promotion of appropriate behaviour to deal with identified climate hazards	NCCAP, 2022 Awareness campaigns and monitoring - Civil Protection Apulia
Urban climate adaptation plans	Promote the formation of Urban Adaptation Strategies and Plans that examine the risk from extreme climate events for the population and the tourism sector. Encourage municipal-scale adaptation initiatives to cope with extreme and life-threatening weather events. Maintenance and adaptation of local transport network, drainage and hydraulic defense works in tourist areas exposed to hydrogeological disruption	Nicu & Fatorić, 2023
Revisions to planning and/or design criteria for road infrastructures	Checks and updates of design criteria for road infrastructure serving tourist areas, taking into account current and future climate changes	MIMS, 2022 NCCAP, 2022
Material monitoring and maintenance or renovation work	Scheduling of the monitoring of microclimatic parameters necessary to be able to assess the degradation of materials and systems characterising cultural heritage or accommodation and tourism facilities. Scheduling of regular maintenance of facilities	Orr et al., 2021 NCCAP, 2022
Promotion of insurance accounts for climate risk management	Promoting the use of innovative insurance products to reduce risks associated with extreme weather events	NCCAP, 2022

Table 3.3.8 Actions to adapt to damage from extreme weather events to accommodation, service, transportation, and cultural and agricultural heritage infrastructure and facilities.

B.6 - Coastal erosion and the reduced availability of beaches

Combating the phenomenon of coastal erosion involves numerous and extensive adaptation measures.

Good beach management practices (Apulia Region, 2020) and combating illegal parking on coastal dunes and back-dunes are necessary to reduce sediment dispersion. In low tourist season periods, one could opt for the installation of windbreaks, or choose more structured naturalistic engineering interventions that favour the restoration of dune cordons and qualify the coastal landscape (MATTM, 2018). The set of adaptation actions formulated for coastal erosion and reduced beach availability in relation to tourism are listed in Table 3.3.9. For all other adaptation measures related to coastal erosion, see section 3.2.

Actions	Description	Bibliographical references
Best practices in beach management and cleanup	Methods and best practices of sandy shoreline management through proper waste management and cleanup, control of coastal architectural works, sand handling, beach nourishment, storm damage management, and reconstruction	MATTM, 2018 Apulia Region, 2020 NCCAP, 2022
Seasonal windbreaks, natural engineering interventions and walkways for landscape and dune ecosystem rehabilitation	Solutions and methods for defense and/or reconstruction of coastal dune systems, using naturalistic engineering techniques, for the benefit of the beach system and landscape	MATTM, 2018 NCCAP, 2022
Vigilance and combating unauthorised parking on beaches and backshore areas	Control and protection of dune and backdune areas from illegal forms of parking and unregulated bivouacs/ gatherings, which cause degradation, littering, and damage to the dune system and landscape	MATTM, 2018 NCCAP, 2022
Planning of access to beaches at high risk of erosion	Identification of planned access measures on beaches at high risk of erosion in order to reduce high levels of tourism pressure in the most vulnerable areas	MATTM, 2018

Table 3.3.9 Actions to adapt to coastal erosion and reduced beach availability.

In conclusion, tourism in Apulia today appears to be a very dynamic, responsive and constantly growing sector.

Regional data on tourism, compiled by the agency "Pugliapromozione" for the Apulia Region, show that the effects of climate change are not yet a problem to the development of the sector, with tourist arrivals and stays growing steadily even in 2022.

However, these data do not allow for the recognition of what and how much effect climate change is having on the regional and coastal tourism sector, because longer time series and greater diversification of the monitored tourism indicators would be needed.

The analysis carried out in this paragraph highlights how climate change could be a threat to the future development of Apulia's tourism sector. A series of impacts induced by climate change, of a direct and indirect nature, are expected to cause variations in the number of tourists choosing to spend a holiday in Apulia or determine a loss of tourist attractiveness of the entire regional and coastal territory.

The expected impacts will be predominantly negative in nature and cannot be avoided. For this reason, adaptation is the only viable solution to limit the negative effects of these impacts and to take advantage of possible development opportunities (IPCC, 2023).

We must also consider how the interconnected nature of tourism to the multiple environmental, social and economic situations of the territory means that this sector may also benefit from adaptation measures applied in other sectors, which in turn are included in the tourism supply chain. This characteristic means that tourism's adaptation to climate change can only succeed by adopting wide-ranging and structured adaptation strategies and plans at a local and multi-sectoral level.

In a region with a strong vocation for tourism such as Apulia, the benefits of adaptation policies for tourism will therefore translate into a greater financial return for the sector and the territory, eliciting appreciation from travellers and residents (Leòn et al., 2021).

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4. Participation, monitoring, and governance

The development of an appropriate adaptation strategy must include discussions with stakeholders. Initiating a dialogue with stakeholders allows for sharing the content of strategies and learning from each other for a shared definition of common goals, agreements on the most urgent adaptation issues and measures.

According to the National Climate Change Adaptation Plan (NCCP 2022), the involvement of stakeholders in the adaptation process involves two steps, namely the selection of stakeholders and the definition of the best way to incorporate them into a successful participatory process. To this end, the 2022 NCCP suggests guidelines, such as: considering time resources by first explaining the number and schedule of events; selecting the most suitable method of integration; protecting against high expectations of stakeholders by specifying the level of integration from the outset; clarifying the roles of stakeholders and experts in the field; explaining what will happen with the results of the process; documenting the steps of the process; and showing appreciation for participation.

To support the activities of the "*AdriaClim*" project, a stakeholder consultation was conducted on March 31, 2023. The Region invited stakeholders from the aquaculture, coastal erosion and tourism sectors. In order to ensure their involvement, a questionnaire was administered prior to the meeting date and repeated on the day of the consultation. The purpose of the questionnaire was to gather information on the consequences of climate change experienced by stakeholders in theirsectors and to find out about possible proposals for adaptation measures.

The meeting was a useful opportunity to discuss the impacts of climate change and share adaptation proposals among the working group and stakeholders.

As climate change is an evolving problem, adaptation policies will imply dynamic social and institutional responses by different stakeholders. In order to verify the effectiveness and outcomes of the adaptation process, monitoring, reporting and evaluation processes are of great importance.

Monitoring provides a description of the progress of the implementation of plans, programmes or strategies, while evaluation analyses their effectiveness. Reporting is tasked with communicating the results of these analyses. Monitoring activities of adaptation strategies and plans should be carried out periodically. The collection of data on the evolving context and achievement of results provides the necessary basis for updating adaptation plans (NCCP, 2022).

Individual plans, therefore, need to be integrated with monitoring systems that should provide all the guidance on approaches to be used, indicators and methods for evaluation. There are two types of approaches: one progress-based and one outcome-based. The *progress-based* approach aims to monitor and evaluate adaptation over time; the results-based approach, on the other hand,analyses the relationship between the adoption of adaptation measures and the reduction of climate change impacts (OECD, 2015).

The use of indicators makes it possible to measure the results of adaptation actions and the progress of their implementation. In addition to monitoring and evaluating the effectiveness of adaptation strategies and/or policies, they are able to describe the evolution of change processes as they provide data that can be compared over time and space.

They are, therefore, useful tools for justifying funding and adaptation programmes, allowing comparisons of different outcomes and also enabling easier communication between policy makers and stakeholders.

The indicators can be divided into three types: impact indicators, risk indicators, and indicators of adaptation actions. In turn, they can be distinguished into qualitative and quantitative (EEA, 2014).

The choice of indicators depends on the goal and object of the monitoring system, but also on the availability of already developed data. In addition, given the complexity of climate change and the diversity of different spatial contexts, it makes more sense for each plan to develop its own indicators, selecting the most relevant ones depending on the process to be monitored.

The 2022 NCCP suggests a list of indicators for the main types of adaptation measures in the database of actions (NCCP Annex IV, 2022). In line with the progress-based and outcome-based approaches, the proposed indicators aim to assess the progress (progress indicators) and effectiveness of the actions (effectiveness indicators). As an example, in the NCCP portfolio of adaptation measures, the absolute (ha) and relative (%) increase in the area of coastal dune cords is given as an effectiveness indicator for the measure "conservation, reconstruction and renaturalisation of coastal areas".

Although various agencies are working to standardise the system of monitoring impacts to climate change, currently Italy does not have a homogeneous system of indicators that would allow development over time of the effects of climate change on various sectors.

Given the importance of monitoring, reporting and evaluation systems, they should be considered as part of the implementation of a Plan. Currently, guidance on the development of monitoring systems is still lacking at the European level, although there are some proposals in this regard.

The European Environment Agency (EEA) in the report "National monitoring, reporting and evaluation of climate change adaptation in Europe" (EEA, 2015), discusses some aspects for the development of monitoring systems, which are set out as follows:

- general outline, purpose, and goal (expressing the rationale and objectives of the system and ensuring smooth insertion of any additions);
- methodology (stating the approach used, information sources, indicators selected and selection criteria used);
- governance and participation (including division of responsibilities, who is involved in monitoring, how stakeholders are involved);
- reporting and use of results (preparation of reports to promote awareness of the results of activities and improvement of certain actions).

If monitoring is a key element in the adoption of medium- to long-term climate change adaptation policies, it becomes essential to devise an appropriate governance model that coordinates adaptation policies and involves public administrations, agencies and society.

In Directorial Decree no. 86 of June 16, 2015, the same by which the National Strategy for Climate Change Adaptation (SNACC) was adopted, provides for the establishment of permanent governance structures at the national level, namely the National Climate Change Adaptation Observatory and the Permanent Forum. The former is a body composed of representatives of the regions with the task of updating the priorities for action and adaptation actions defined in the NCCP. It is also in charge of activity monitoring and evaluation of interventions and proposals put forward by regions or other entities.

The Permanent Forum is an advisory-dissemination body with the role of informing society and stakeholders on the topic of adaptation and promoting discussion on these issues. These two bodies are joined by a technical secretariat to support the analysis of technical information needed in the planning phase of the NCCP 2022.

One of the most pressing of the governance issues is to adapt adaptation issues to planning and programming tools. Regions also need to have a governance system that integrates and coordinates action programs across sectors by involving the national and local levels. The LIFE project "Master Adapt" (2019) also addressed governance in the document "Guidelines for Regional Climate Change Adaptation Strategies."

According to the LIFE "Master Adapt," the governance design can be constructed on the basis of existing structures suitable for addressing adaptation, or it can involve the establishment of new structures with the role of coordination. This choice remains the prerogative of the region based on what it considers to be the most appropriate way to arrive at the implementation of its climate change adaptation strategy (LIFE, Master Adapt, 2019).

The annex of the NCCP 2022 'Methodologies for the definition of regional climate change adaptation strategies and plans' (NCCP Annex I, 2022), proposes to develop the governance structure at the regional level through three bodies: a coordination structure, a technical-scientific support structure and an advisory body.

The coordination structure should carry out consultation and mentoring services for regional sector and local government leaders on climate change adaptation. In addition, other functions are the responsibility of this body, such as:

- coordination of strategy implementation, monitoring and reporting activities;
- Support for Environmental Authorities;
- integration of adaptation issues through updating information systems;
- periodic evaluations of the adaptation strategy;
- updating the schedule of responsibilities of the various administrative structures;
- support in the drafting of planning tools.

The coordination structure could take the form of a steering committee to promote technical-political confrontation in order to set the direction of strategic choices and define the priorities to be implemented (NCCP Annex I, 2022).

The scientific and technical support structure includes experts from the scientific research sector, namely from research institutions, universities and regional agencies. In addition to playing an important role in developing innovative technologies, monitoring and sharing data and information, the scientific and technical support body could be given the tasks of:

- characterisation of the climatic and spatial context;
- assessment of climate change impacts and risks at the sectoral level;
- Vulnerability assessment of specific sectors;
- development of systems for evaluating the effectiveness of the adaptation strategy;
- participation in the drafting of climate change adaptation plans;
- coordination of the various activities of the other bodies.

In order to ensure participation in decision-making processes and the involvement of stakeholders, the advisory body could contribute to the formulation of regional or local climate policies, the promotion of affected interests and the communication of needs due to climate change impacts (NCCP Annex I, 2022).

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