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CRESCO Adria

A3.3 – SURVEY IN PILOT AREAS

D.3.3.1. Reports on observed climate change impacts

A3.3 – Survey in pilot areas – the Town of Crikvenica

D.3.3.1. Reports on observed climate change impacts– the Town of Crikvenica

Project Acronym :	CRESCO Adria
Project ID Number:	ITHR0200245
Project Title:	Climate RESiliEnt COastal planning in Adriatic
Priority Axis 2:	Green and resilient shared environment
Specific objective:	• The goal is to enhance climate resilience in Adriatic coastal regions through upgraded spatial planning, integrating scientific research, and defining strategic guidelines for sustainable space management. • The goal is to educate students, practitioners, and stakeholders on extreme weather events caused by climate change, focusing on data collection, modeling, legal standards, and socially responsible coastal zone management. • The goal is to build local capacity in coastal areas to reduce climate change risks and enhance resilience through community involvement, awareness-raising, training, and sustainable adaptation planning.
Work Package Number:	3
Work Package Title:	WP3 – Climate Change Adaptation Plans for Local Area
Activity Number:	A.3.3. / D.3.3.1.
Activity Title:	Survey in pilot areas / Reports on observed climate change impacts
Partner in Charge:	Town of Crikvenica
Partners involved:	EFRI, IPP PGC, GRADRI, Sali, Crikvenica, ABREG, UniCam
Status:	Draft
Distribution:	

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1. Introduction

Purpose and the objectives

Within the framework of the CRESCO Adria INTERREG IT-HR 2021-2027 project, work package WP3, which has the specific objective of improving the climate change adaptation capacities of certain pilot coastal areas, a Climate Change Adaptation Plan for the Town of Crikvenica is being developed. Through WP3, it is planned to develop Climate Change Adaptation Plans through capitalization of documents and guidelines developed within the framework of the AdriAdapt Interreg IT-HR project (applying the principles of integrated coastal zone management).

This document was developed within the framework of activity *A3.3. – Survey in pilot areas* and includes the delivery of this activity under the designation *D.3.3.3. Reports on observed climate change impacts* which are analysed provide an overview of the data on climate change impacts, in relation to the previously established priority climate change impacts which are established within the framework of activity *A.3.1. Setting the vision - defining pathways to climate resilience in accordance with local* characteristics, selecting an appropriate response, within the framework of the delivery under the designation *D.3.1.1. State of the art analysis.*

Since a number of existing documents and studies covering the area of the City of Crikvenica also address the impacts of climate change, **no additional research was conducted for this document. Instead, key data and findings from existing studies have been taken and presented in this document** so that they can be used in further development of the project.

2. Overview of selected priority climate change impacts and description of data presentation methods

After conducting an analysis of individual climate change impacts on the Town of Crikvenica, a consolidated assessment was prepared within the framework of document *D.3.1.1. State of the art analysis*, which allows determining those impacts that require the most urgent adaptation. The identified impacts with their priority assessment are shown in the following table.

Table 1: Overall risk assessment

Impact of climate change	Probability (1 –5)	Intensity (1 – 5)	Risk = V × I	Priority
Extreme weather events (heatwaves, storms, and severe weather)	5	4	20	Very High
Increase in droughts and decrease in precipitation	5	3	15	Moderate
Average and extreme sea level rise	5	3	15	Moderate
Reduced availability of drinking water	2	2	4	Low
Increasing sea temperature	4	3	12	Moderate
Risk of forest fires	5	4	20	Very High
Impact on tourism	5	4	20	Very High
Change in biodiversity	4	3	12	Moderate
Infrastructure stress	3	3	9	Low

This document provides an overview of the available data **for the identified impacts of climate change that have been assessed as very high priority and moderate priority.**

Given that a number of existing documents and studies for the Town of Crikvenica also include information on the impacts of climate change, **no special research was conducted to prepare this document, but rather the most important data and conclusions from the studies were taken** to serve as further elaboration in the project.

In preparing this document, data specifically related to the Town of Crikvenica, concerning rising sea temperatures and changes in biodiversity, were not available and therefore could not be used. Such data are not collected at the municipal level, but rather for a broader region, so they cannot be presented separately for the Town of Crikvenica in this document.

This document does not present or analyse data on the impact of climate change on tourism, since there are currently no sufficiently reliable and systematically collected indicators for such an analysis. Namely, the impact of climate change on tourism is not simply directly measurable, and the methodologies and monitoring systems that would provide quality and well-founded data have not yet been fully established.

Data and information on climate change assessments and projections were taken from the document Action Plan for Energy and Climate Sustainable Development of the Town of Crikvenica – SECAP, December 2025.

The climate projection in the Republic of Croatia until 2040 with a view to 2070 was carried out with simulations of the "historical" climate for the period 1971 - 2005 (reference period) and simulations for the future time periods 2011 - 2040 and 2041 - 2070. Simulations and analyses for the territory of Croatia were made based on the results of numerical integrations with the regional climate model (RCM) RegCM at a spatial resolution of 12.5 km
Future climate change was modelled considering two scenarios for the development of greenhouse gas concentrations in the future (RCP4.5 and RCP8.5) as determined by the Intergovernmental Panel on Climate Change (IPCC).

The RCP4.5 scenario is considered a more moderate scenario and is characterized by a medium level of greenhouse gas concentrations with relatively ambitious expectations of their reduction in the future, which would peak around 2040. The RCP8.5 scenario is considered an extreme scenario and is characterized by a continuous increase in greenhouse gas concentrations, which by 2100 would be up to three times higher than today.

The SECAP document only considers the RCP8.5 scenario, which is currently more likely than the moderate RCP4.5 scenario.

3. Review of available data for identified climate change impacts

Extreme weather events (heatwaves, storms, and severe weather)

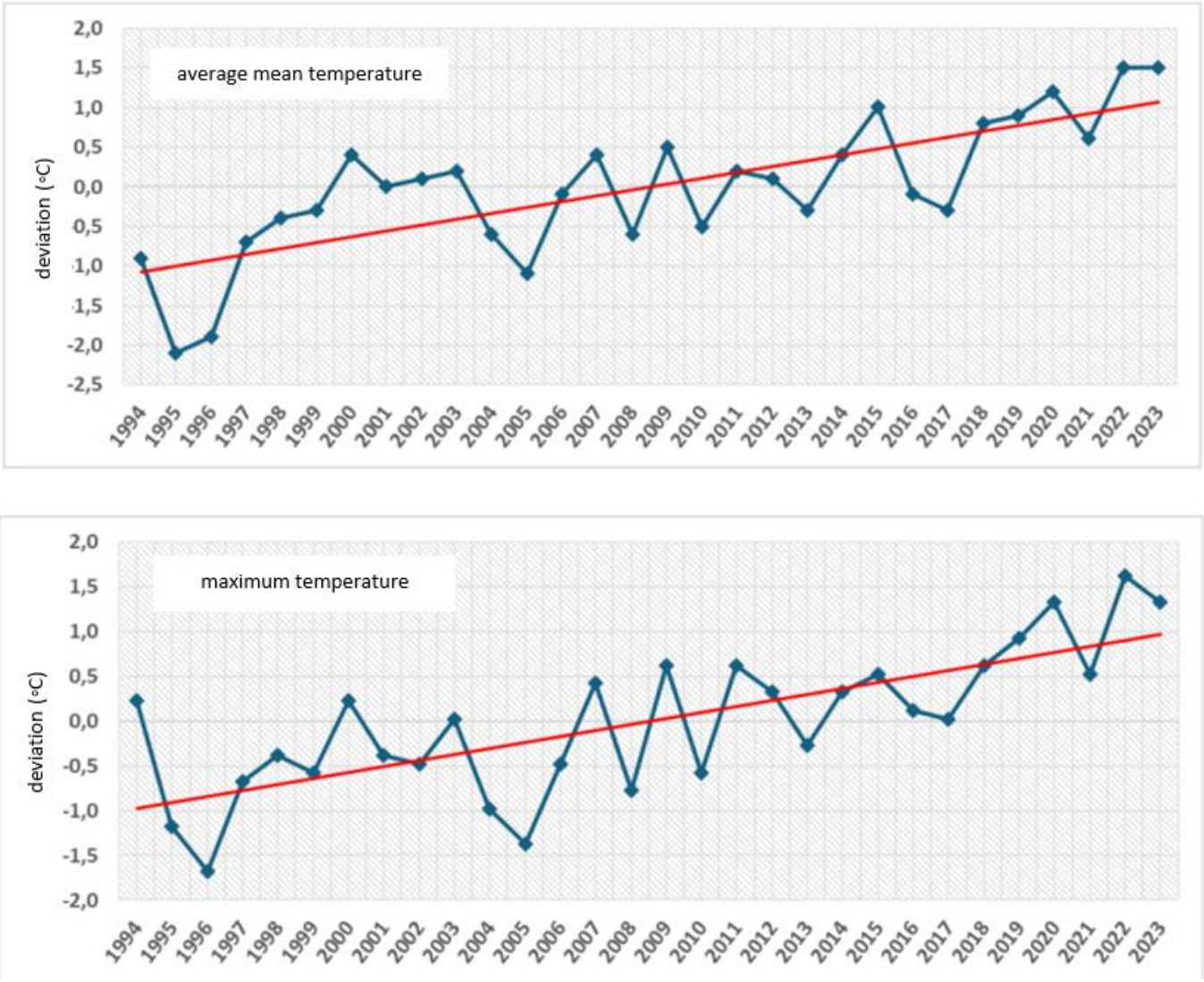
In the area of the Town of Crikvenica, extreme weather conditions are most pronounced during the summer months, but their occurrence can also extend to the transitional seasons. The effects are multiple – from health risks, to property damage, to disruption of tourism and traffic activities.
The most significant impacts of extreme weather conditions for the area of the Town of Crikvenica are:

- occurrence of heat islands
- floods

Heat waves

The time series of deviations of the annual averages of the mean, maximum and minimum daily air temperatures from the average for the observed period (1994 - 2023) indicates a trend of increasing mean and maximum temperatures. The trend of heat indices is consistent with the above, and in the area in question, a trend of increasing hot days (Tmax > 30 °C) and an increase in the number of tropical nights (Tmin > 20 °C) was recorded.

Figure 1: Deviation from the average mean and maximum temperature at the Crikvenica climatological station for the period 1994 - 2023. Data source: DHMZ, taken from the Action Plan for Energy and Climate Sustainable Development of the Town of Crikvenica - SECAP, December 2025.



According to the SECAP document, the results of climate modelling with boundary conditions of the four observed global models indicate the following changes in the future temperature regime compared to the reference period P0:

- an increase in the mean annual temperature in the period P1 in the range of 0.9 °C to 1.8 °C, and in the period P2 to an increase in the range of 2.1 °C to 3.3 °C
- an increase in the mean minimum annual temperature in the period P1 in the range of 0.9 °C to 1.7 °C, and in the period P2 to an increase in the range of 1.0 °C to 1.4 °C
- an increase in the mean maximum annual temperature in the period P1 in the range of 1.0 °C to 1.8 °C, and in the period P2 to an increase in the range of 2.1 °C to 3.3 °C

The observed warming is also reflected in all temperature extreme indices by positive trends in warm temperature indices. From the temperature indices during the reference period (1971 - 2005) and in future periods (until 2070), the following trends were observed:

- the total annual number of tropical nights (TR20), i.e. the number of days with a minimum air temperature ≥ 20 °C
- the total annual number of hot days (HD), i.e. the number of days with a maximum daily air temperature ≥ 30 °C.

The results of climatological modelling with boundary conditions of the four observed global models indicate the following changes in future temperature indices compared to the reference period P0:

- an increase in the mean annual number of tropical nights in the period P1 in the range from 4.4 to 15.4, and in the period P2 in the range from 8.1 to 40.5
- an increase in the mean annual number of hot days in the period P1 in the range from 6.2 to 18.4, and in the period P2 in the range from 12.1 to 42,

FIgure 2: Time series of the number of tropical nights (Tmin ≥ 20 °C) for the Town of Crikvenica for four integrations with the RegCM model. Data source: DHMZ, taken from the Action Plan for the Sustainable Energy and Climate Development of the Town of Crikvenica – SECAP, December 2025.

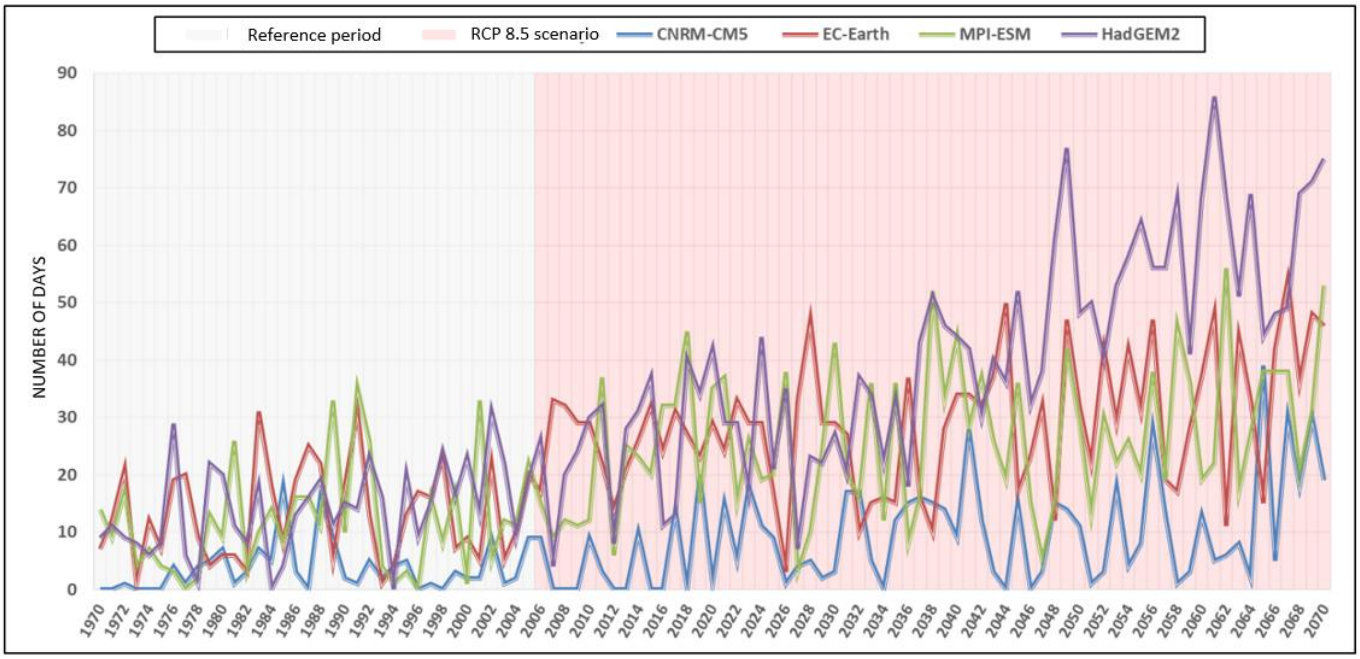
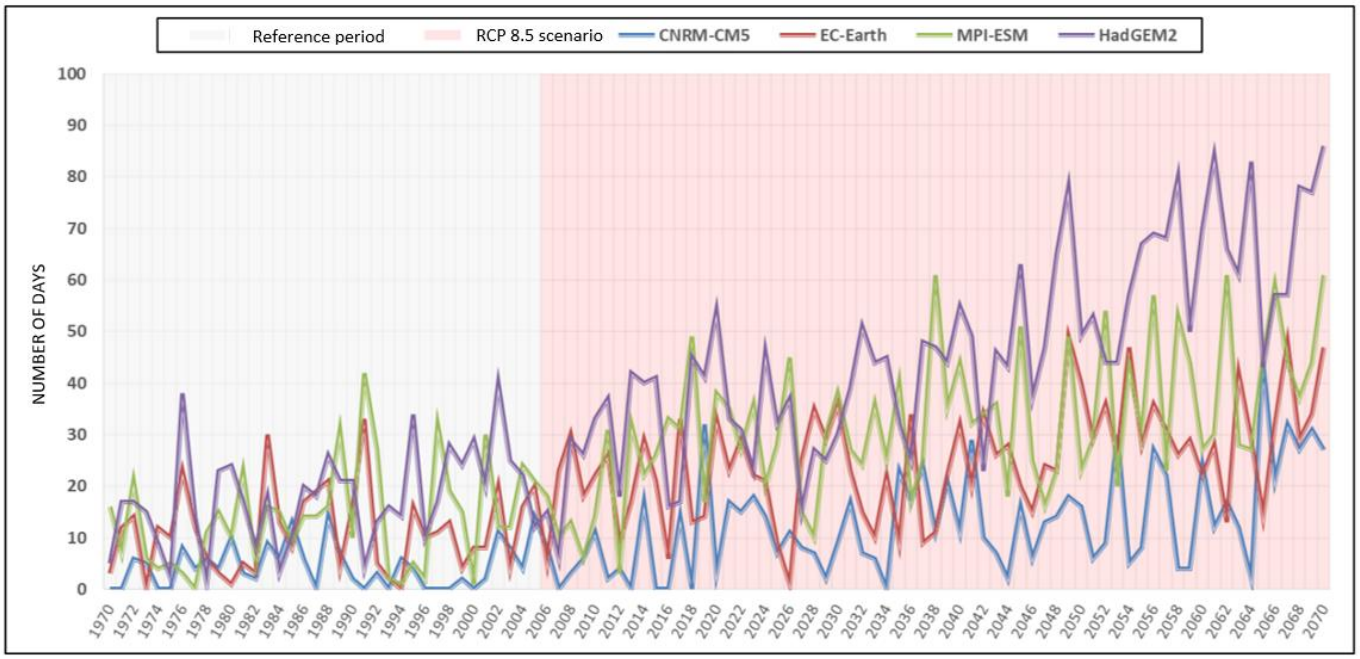


FIgure 3: Time series of the number of hot days (Tmax ≥ 30 °C) for the Town of Crikvenica for four integrations with the RegCM model. Data source: DHMZ, taken from the Action Plan for the Sustainable Energy and Climate Development of the Town of Crikvenica – SECAP, December 2025.

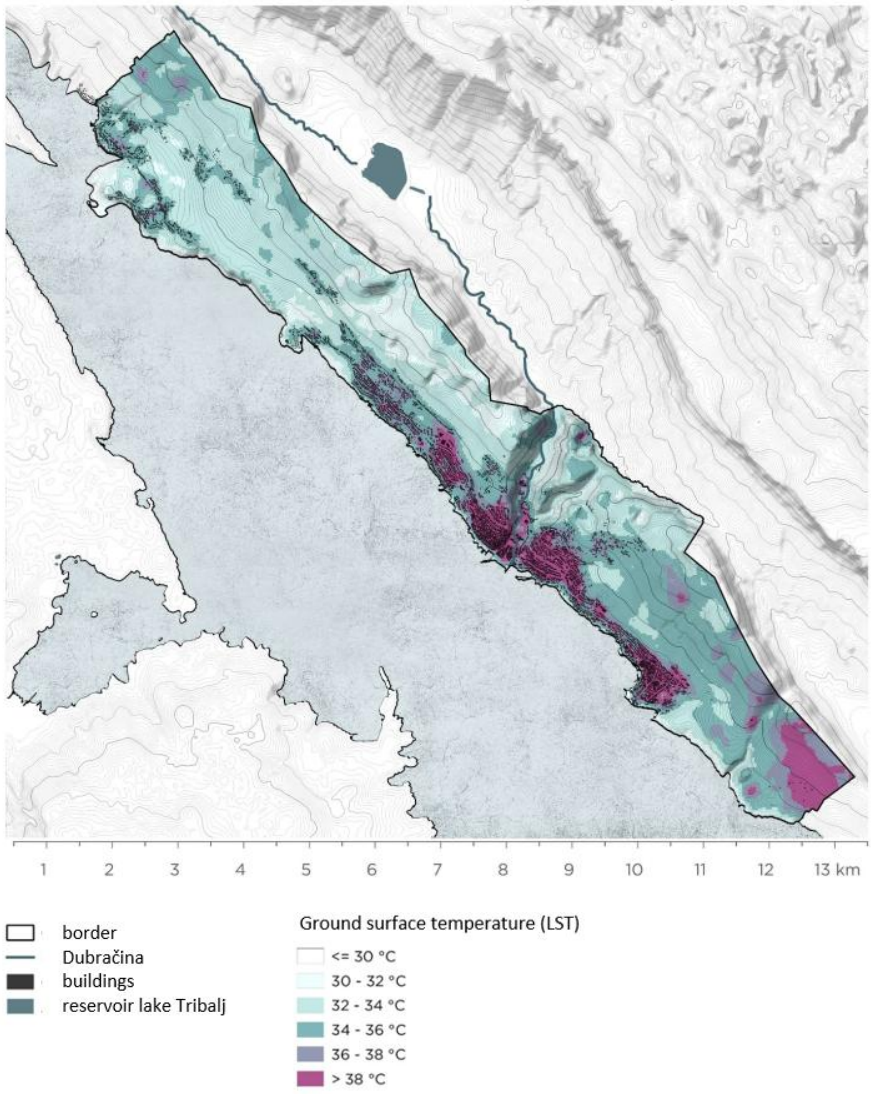


Heat islands

The Green Urban Renewal Strategy for the Town of Crikvenica analysed data and spatial distribution of heat during the summer months (June, July and August) in the City. It was determined that the differences in surface soil temperature between the urban area (covered with concrete and asphalt) and the surrounding green areas exceed 5, and in some places even over 10. In the administrative area of the Town of Crikvenica, several locations with increased surface soil temperature compared to the surrounding area stand out:

- the urban area of Crikvenica at the mouth of the Dubračina Creek,
- the area of shopping centers in the northern part of Crikvenica,
- the residential area in the southeastern part of Crikvenica,
- the urban center of the settlement of Selce and
- the agricultural area along the road to Novi Vinodolski.

FIgure 4: Heat island map / Source: Strategy for green urban renewal of the administrative area of the Town of Crikvenica, 2023



Floods

According to data from Croatian Waters, the entire area of the Town of Crikvenica is located within a zone with a potentially significant risk of flooding, with climate change further increasing exposure, especially in the coastal zone. The flood risk assessment includes three scenarios: high (25 g), medium (100 g) and low probability (1000 g) flooding, but the impact of climate change was considered only for floods caused by sea level rise.

Three key types of flooding are important for the Town of Crikvenica:

- Floods caused by sea level rise – the rise in average and extreme sea levels leads to flooding of lower coastal zones, especially during storm tides and strong southerly winds. In the coastal area, due to the relatively rapid rise in sea level, floods would affect piers and beaches, but on certain segments of the coastline, the risk of flooding also affects individual residential buildings. The expected depth of flooded water for the high probability scenario for the coastal area is up to 2.5 m.

- Floods from the Dubračina Creek – due to heavy rainfall in the basin, the water level of the Dubračina Creek rises sharply and overflows the banks. The most endangered area is the area of the Dubračina estuary in the city center, where key facilities are located: a school, a bus station, a fire station, a football field and catering facilities.

- Urban floods due to extreme precipitation, which occur due to short-term, but very intense rains. They burden the precipitation system and cause flooding of roads and low-lying buildings.

According to official data from Croatian Waters obtained in April 2023, flood risks are closely related to the Dubračina riverbed and the coastal zone. The high probability of flooding is mostly related to the coastal area of the Town of Crikvenica, while the medium and low probability are also related to the area of the Dubračina river. In all three scenarios, the most endangered area from flooding is the urban area of the Dubračina estuary, where there is a parking lot, a bus station, a school, a fire station, a football field, and various catering and tourist facilities.

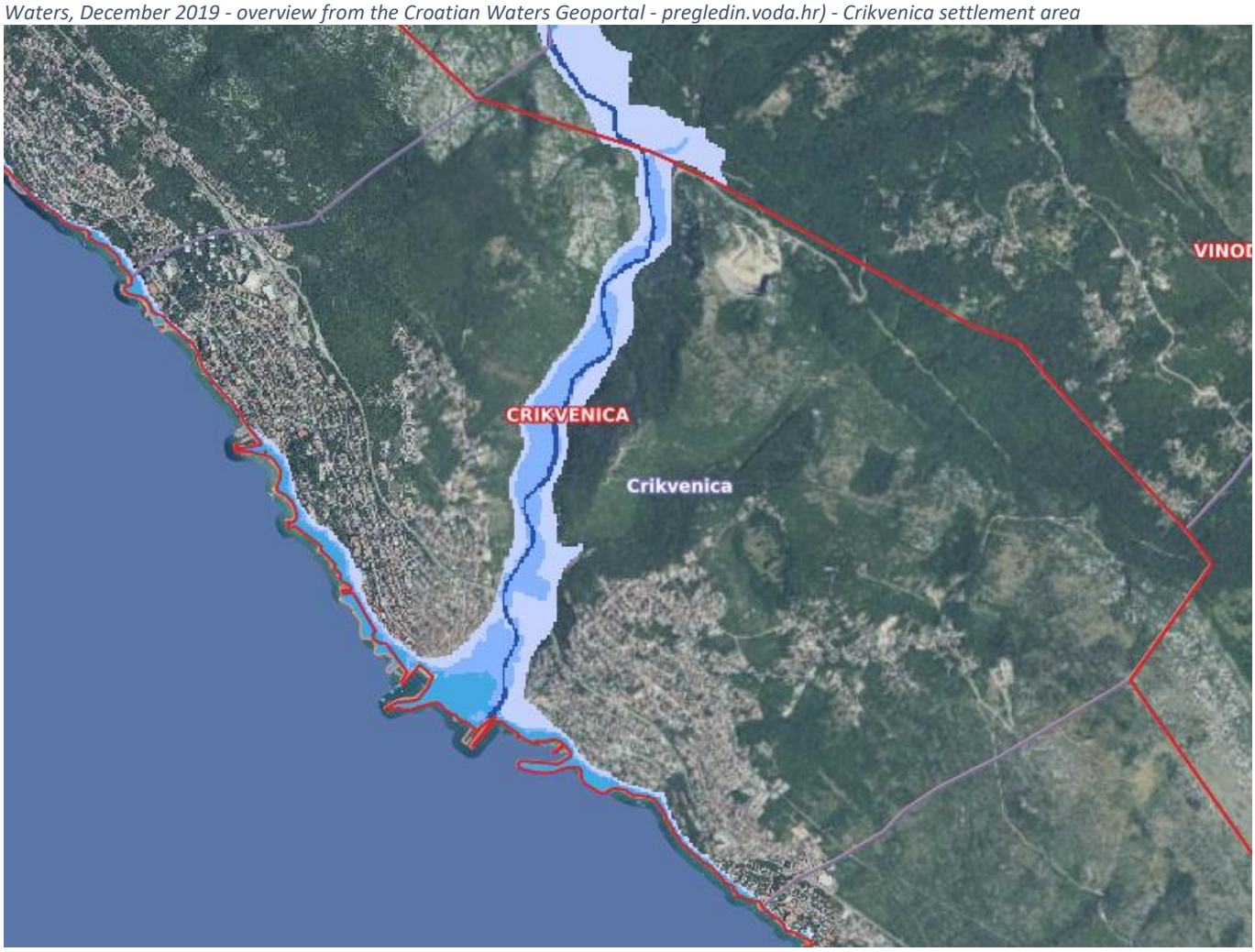
In the medium and low probability scenarios, the most endangered area, in addition to the urban area at the estuary, also includes the area along the Dubračina, where the Crikvenica substation stands out among the facilities at risk.

In the coastal area, due to the relatively rapid increase in sea level, floods would affect piers and beaches, but on certain segments of the coastline, the risk of flooding would also affect individual residential buildings. The expected depth of flood water for the high probability scenario for the coastal area is up to 2.5 m, while for the urban area along the Dubračina it is up to 1.5 m.

The expected depth of flood water for the medium probability scenario for the coastal area is over 2.5 m, while for the urban area it is up to 2.5 m.

In the area of the substation, the values of the medium probability flood exceed 2.5 m. In the low probability scenario, the flood depth for the entire area along the Dubračina valley is over 2.5 m.

FIgure 5: Threat map - overview map of flood hazards by probability of occurrence (River Basin Management Plan 2022-2027, Croatian Waters, December 2019 - overview from the Croatian Waters Geoportal - pregledin.voda.hr) - Crikvenica settlement area



Map legend:
Flood hazards, three flooding scenarios in 2020
- low probability
- medium probability
- high probability
- water bodies

FIgure 6: Threat map - overview map of flood hazards by probability of occurrence (River Basin Management Plan 2022-2027, Croatian Waters, December 2019 - overview from the Croatian Waters Geoportal - pregledin.voda.hr) - Jadranovo settlement area

Map legend:
Flood hazards, three flooding scenarios in 2020
low probability
medium probability
high probability
water bodies

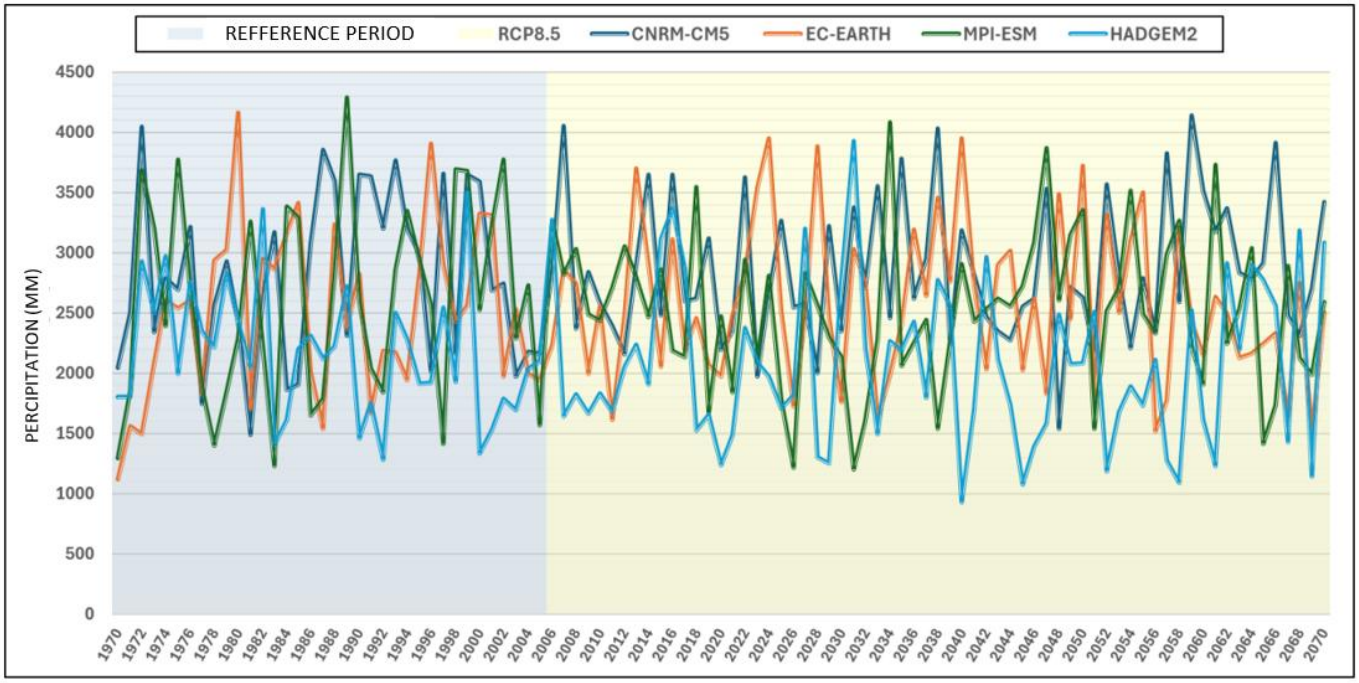
FIgure 7: Threat map - overview map of flood hazards by probability of occurrence (River Basin Management Plan 2022-2027, Croatian Waters, December 2019 - overview from the Croatian Waters Geoportal - pregledin.voda.hr) – Dramalj settlement area

Map legend:
Flood hazards, three flooding scenarios in 2020
- low probability
- medium probability
- high probability
- water bodies

Increase in droughts and decrease in precipitation

According to climate models, no significant changes in average precipitation are expected until 2070. Sudden changes from year to year characterize climate variability, but interannual variability is small and without major differences between seasons.

FIgure 8: Time series of total annual precipitation [mm] for the Town of Crikvenica for four integrations with the RegCM model. Data source: DHMZ, taken from ACTION PLAN FOR ENERGY AND CLIMATE SUSTAINABLE DEVELOPMENT OF THE TOWN OF CRIKVENICA – SECAP, December 2025.)



If we look at the change in the total amount of precipitation in the seasons (DJF - winter, MAM - spring, JJA - summer, SON - autumn) in the period P1: 2011 - 2040 and P2: 2041 - 2070 compared to the period P0: 1971 - 2005, and in the relative amount [(P1-P0)/P0] and [P2-P0)/P0] expressed in percentages, the changes in precipitation have different signs by season and according to the simulations with different boundary conditions of the global models. If we look at the mean of the ensemble of models used, the simulations for the period P1 indicate a decrease in precipitation in all seasons, which is most pronounced in the summer period, and minimal in the winter. In the period P2, the models predict a similar decrease in precipitation in spring, summer and autumn, and an increase in precipitation in the winter period.

In addition to temperature, the SECAP document also analyses precipitation extremes:

- maximum daily precipitation during the year (Rx1d; mm),
- number of very wet days, i.e. number of days with daily precipitation ≥ 20 mm (R20 - heavy precipitation days),
- consecutive series of days with daily precipitation ≥ 1 mm - duration of dry periods (CDD - consecutive dry days, R ≥ 1 mm) and
- consecutive series of days with daily precipitation < 1 mm - duration of rainy periods (CWD - consecutive wet days, R < 1 mm).

The expected changes in the mean number of days with very high precipitation (R20) according to the analyzed RegCM simulations indicate that there will be no change in the P1 period, while in the P2 period they indicate the possibility of their decrease, if the ensemble mean calculated from four numerical integrations with the RegCM model is observed.

The expected changes in the maximum daily precipitation (Rx1d) according to the analyzed RegCM simulations indicate the possibility of their increase between the current climate and future climate periods for all individual model integrations except for the boundary conditions of the EC-Earth model in which there is a possibility of a decrease in the maximum daily precipitation.

The expected change in the mean number of consecutive dry days with precipitation less than < 1 mm according to the analyzed RegCM simulations does not have an unambiguous signal.

For the P1 period, most models (except EC-Earth) indicate the possibility of their increase with a difference between the current climate and the future climate period ranging from 0.9 to 12.9 days. For the P2 period, there is a possibility of an increase of up to 15.8 days with the boundary conditions of most global models, except for the CNRM-CM5 boundary conditions, where a slight decrease of 0.1 days is predicted.

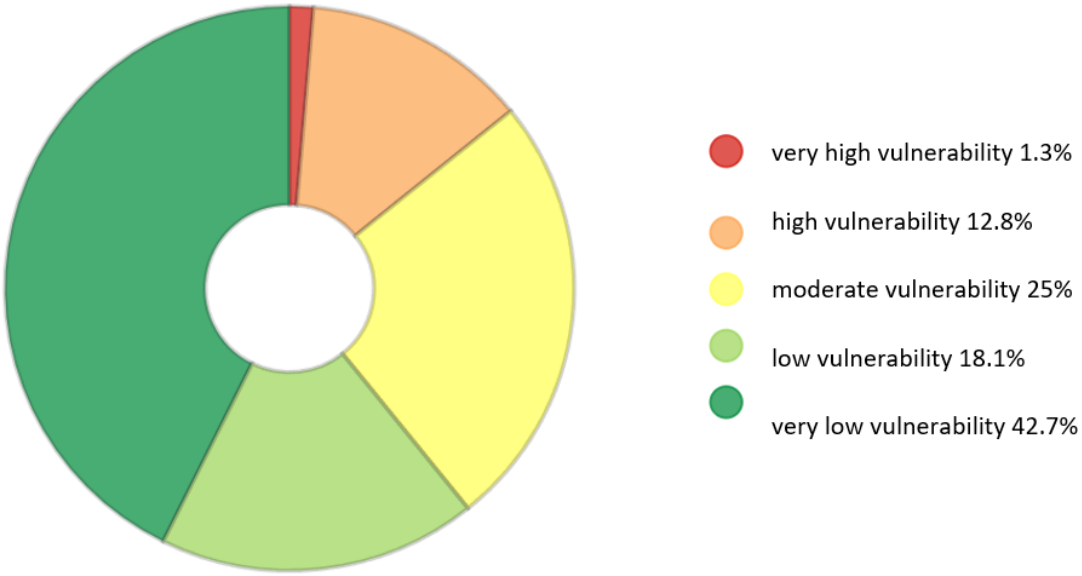
The expected change in the mean number of consecutive rainy days with precipitation ≥ 1 mm according to the analyzed RegCM simulations shows that there will be no significant shifts. In the P1 period, only the HadGEM2 model predicts a decrease of up to 0.2 days, while other models indicate a possibility of their increase between the current climate and the future climate period of up to 1.1 days. For the P2 period, most models also do not predict significant changes

in the lengths of the precipitation periods, only the simulations with the CNRM-CM5 boundary conditions give an increase of a maximum of 0.8 days.

Average and extreme sea level rise

In 2021, the document Analysis of the Vulnerability of the Coastal Area of Primorje-Gorski Kotar County due to sea level rise was developed (Faculty of Civil Engineering in Rijeka and Institute for Spatial Planning of the Primorje-Gorski Kotar County, 2021), which defines the methodology for calculating the vulnerability index of the coastal area to sea level rise. This document determined the vulnerability of the coastline for the entire area of the County according to the defined methodology. For the Town of Crikvenica, a vulnerability index of 2.12 was determined, which is classified as low vulnerability, however, the determined index is above the average value for the county. According to the data of the document in question, the share of the coastline of the Town of Crikvenica that is categorized as very high vulnerability is 1.3%, while the share of the coastline categorized as high vulnerability is 12.8%.

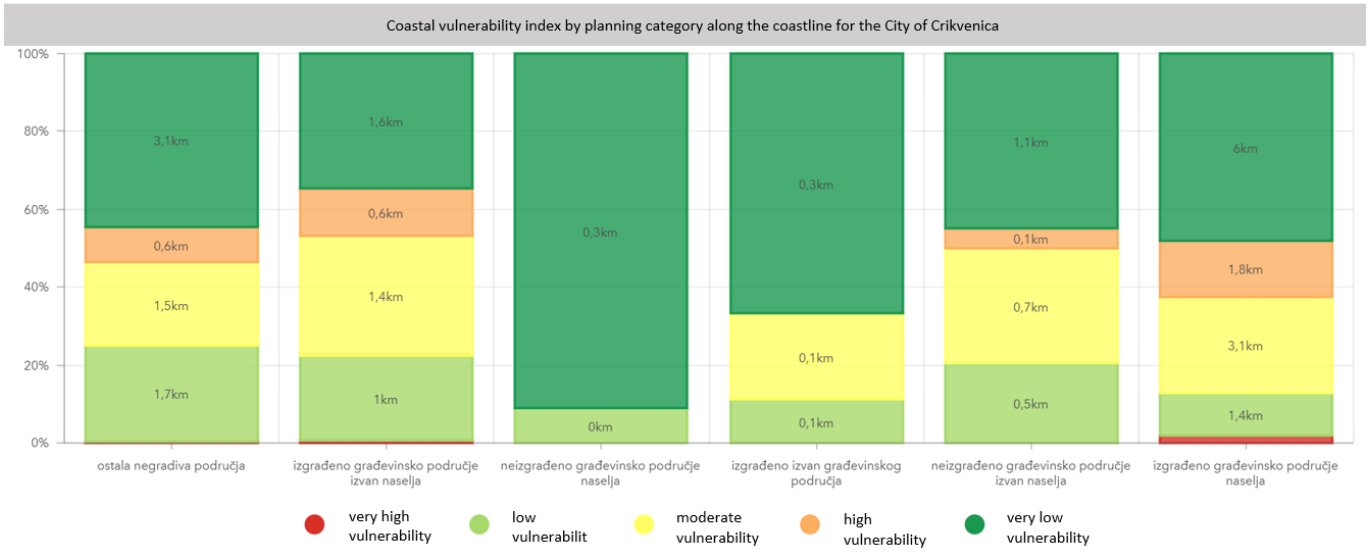
FIgure 9: Coastal Vulnerability Index for the Town of Crikvenica // Source: Coastal Vulnerability Index of the Primorje-Gorski Kotar County (https://gisportal.pgz.hr/portal/apps/experiencebuilder/experience/?id=8b96f9ed8bb24595bb1aab7d1603e16b&page=page_0)



However, it should be emphasized that according to the spatial representation of the coastal vulnerability index, the area of very high vulnerability and high vulnerability is located precisely in the coastal area of the central part of the settlement of Crikvenica. Also, in relation to the planning categories along the coastline, areas of moderate, high and very high vulnerability are mostly located in areas adjacent to built-up or unbuilt parts of construction areas.

FIgure 10: Spatial display of the coastal vulnerability index – Town of Crikvenica // Source: Coastal vulnerability index of the Primorje-Gorski Kotar County (https://gisportal.pgz.hr/portal/apps/experiencebuilder/experience/?id=8b96f9ed8bb24595bb1aab7d1603e16b&page=page_0)

FIgure 11: Coastal vulnerability index by planning category along the coastline for the Town of Crikvenica // // Source: Coastal vulnerability index of the Primorje-Gorski Kotar County (https://gisportal.pgz.hr/portal/apps/experiencebuilder/experience/?id=8b96f9ed8bb24595bb1aab7d1603e16b&page=page_0)



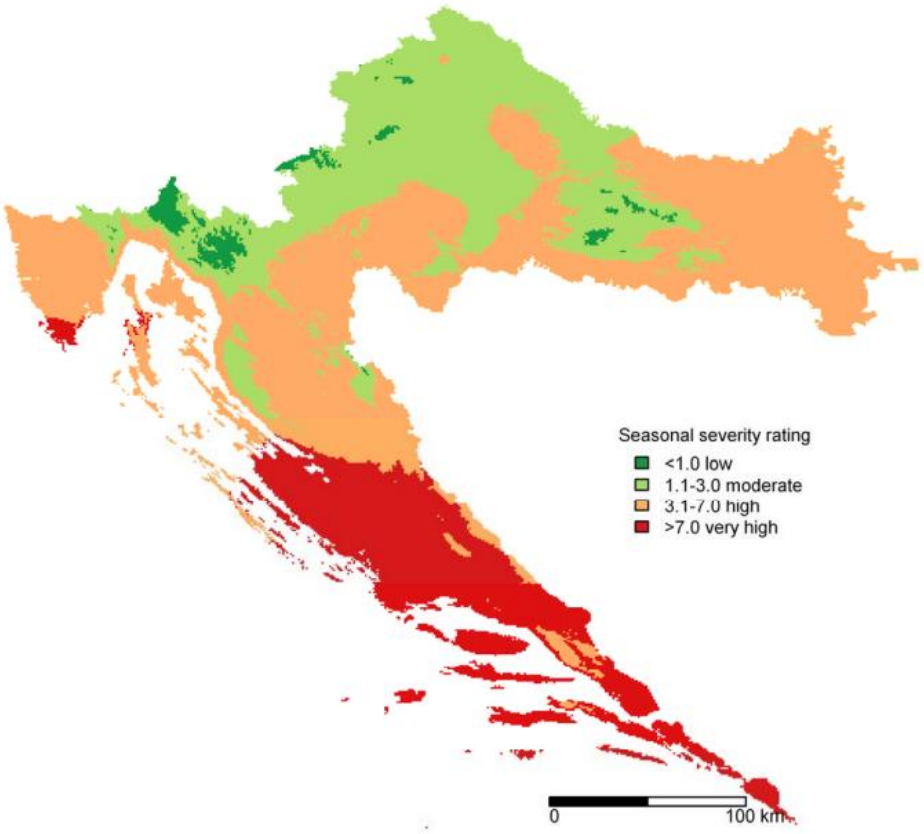
Risk of forest fires

Dry periods, which are occurring more frequently and intensively due to climate change, significantly increase the risk of fire outbreaks and their spread in natural ecosystems. In the hinterland of the Town of Crikvenica, due to forestation and macchia vegetation, the area is susceptible to fire hazards. Fires pose a serious threat to the safety of people, property and the environment.

Each location has its own fire regime that can be described by derived quantities that are the result of the interaction of the humidity/dryness of natural fuel material and the climatic conditions of a particular area. One of such dimensionless quantities is the severity rating. It can be monthly (MSR) and seasonal (SSR) and is determined by the Canadian method for assessing the danger of vegetation fires. The severity rating contains meteorological conditions and the moisture state of dead forest fuel material and serves as a climate-fire representation of the average condition in a certain area. It is generally considered that the potential danger of vegetation fires is very high if the average seasonal severity SSR > 7.

The combination of high temperatures and long dry periods can lead to forest fires. The Canadian Fire Weather method and the Seasonal Severity Rating (SSR) index are used to assess the potential risk of forest fires. The average SSR for the period 1991-2020 is 4-6 in the coastal area of the Town of Crikvenica, and 2-4 in the mountainous hinterland. The percentage increase compared to the period 1961-1990 is 20-30% in the area of the Town of Crikvenica (Horvath et al., 2023).

FIgure 12: Map of the potential fire hazard index of seasonal severity (SSR) vegetation in the fire season (June-September) in the period 1981 - 2010, taken from the Revision of the Major Accident Risk Assessment for the Town of Crikvenica, March 2023.



Below is a table showing the number of fires in open spaces over the past 10 years. The highest number of fires in open spaces was recorded in 2012.

Table 2: Number of open space fires in the Town of Crikvenica, taken from the Revision of the Major Accident Risk Assessment for the Town of Crikvenica, March 2023

TYPE OF FIRE	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	ZBROJ
Open space fires	18	28	16	17	68	20	10	27	19	48	271

4. Data sources

Strategic and development documents, reports

- Green Urban Renewal Strategy for the Administrative Area of the Town of Crikvenica
- Action Plan for Energy and Climate Sustainable Development of the Town of Crikvenica – SECAP, December 2025.
- Major Accident Risk Assessment for the Town of Crikvenica, Revision of the Major Accident Risk Assessment, March 2023.
- Analysis of the vulnerability of the coastal area of Primorje-Gorski Kotar County due to sea level rise, (University of Rijeka, Faculty of Civil Engineering, Institute for Spatial Planning of Primorje-Gorski Kotar County, 2022)
- Analysis of the threat of coastal flooding of vulnerable settlements of Primorje-Gorski Kotar County (University of Rijeka, Faculty of Civil Engineering, Institute for Spatial Planning of Primorje-Gorski Kotar County, 2023)

Internet data sources

- https://zavod.pgz.hr/PDF/Analiza_ranjivosti_obalnog_podrucja_PGZ_zbog_podizanja_razine_mora.pdf
- Institute for Spatial Planning of the Primorje-Gorski Kotar County - Coastal Zone Vulnerability Monitor: https://gisportal.pgz.hr/portal/apps/experiencebuilder/experience/?id=8b96f9ed8bb24595bb1aab7d1603e16b&page=page_0
- https://preglednik.voda.hr/?lang=hr

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