Deliverable Phase 1 – Climate risk assessment

Heat-wave risk analysis & adaptation for vulnerable groups

(LUGIA)

Spain/Huércal-Overa

HORIZON-MISS-2021-CLIMA-02-01 - Development of climate change risk assessments in European regions and communities based on a transparent and harmonised Climate Risk Assessment approach

Funded by the European Union

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101093864. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

Document Information

Deliverable Title	Phase 1 – Climate risk assessment
Brief Description	This deliverable reports the first phase of the **LUGIA project** in **Huércal-Overa (Almería, Spain)**, assessing the risks of **heat waves** on vulnerable groups using **CLIMAAX tools**. It includes a detailed characterization of the municipality's territorial, natural, socioeconomic, and climate context, followed by the application of four analytical workflows: climate prediction with European and local definitions of heat waves, and risk assessment using both historical satellite data and future climate projections. Results identify critical areas of exposure and vulnerability, complemented by an initial stakeholder mapping. The document concludes with adaptation priorities, general conclusions, and next steps.
Project name	Heat-wave risk analysis & adaptation for vulnerable groups (LUGIA)
Country	Spain
Region/Municipality	Huércal-Overa
Leading Institution	Municipality of Huércal-Overa
Author(s)	CESYT, subcontracted company by the Municipality for the work: • Juan Bautista Tomás Gabarrón • Almudena Sánchez Centeno • Antonio Ayllón Bermejo • Pablo Lorenzo Domínguez
Deliverable submission date	04/09/2025
Final version delivery date	dd/mm/yyyy
Nature of the Deliverable	R – Report
Dissemination Level	PU - Public

Version	Date	Change editors	Changes
1.0	04/09/2025	Municipality of Huércal-Overa	Deliverable submitted
2.0	…	CLIMAAX's FSTP team	Review completed
5.0	…		Final version to be submitted

Table of contents

List of figures

List of tables

Abbreviations and acronyms

Abbreviation / acronym	Description
AEMET	Agencia Estatal de Meteorología (Spanish State Meteorological Agency)
CDS	Copernicus Climate Data Store
CLIMAAX	Climate risk and vulnerability assessment framework and toolbox
CORDEX (EURO-CORDEX)	Coordinated Regional Climate Downscaling Experiment for Europe
CRA	Climate Risk Assessment
CSIC	Consejo Superior de Investigaciones Científicas (Spanish National Research Council)
EPSG	European Petroleum Survey Group
EU	European Union
GCM	Global Climate Model
GIS	Geographic Information System
INE	Instituto Nacional de Estadística (National Statistics Institute of Spain)
IPCC	Intergovernmental Panel on Climate Change
LST	Land Surface Temperature
LUGIA	Local Urban Green Infrastructure Adaptation
MFE	Mapa Forestal de España (Spanish Forest Map)
MoMo	Daily Mortality Monitoring System (Carlos III Health Institute)
NUTS	Nomenclature of Units for Territorial Statistics
OLI/TIRS	Operational Land Imager / Thermal Infrared Sensor
PAAC	Plan Andaluz de Acción por el Clima (Andalusian Climate Action Plan)
PGOU	Plan General de Ordenación Urbana (General Urban Development Plan)
PNACC	Plan Nacional de Adaptación al Cambio Climático (Spanish National Climate Change Adaptation Plan)
RCP	Representative Concentration Pathway
RCM	Regional Climate Model
SIOSE	Sistema de Información sobre Ocupación del Suelo en España (Land Occupation Information System of Spain)
SAC	Special Area of Conservation
UTCI	Universal Thermal Climate Index

Executive summary

This deliverable presents the first phase of the **LUGIA project**, led by the Municipality of Huércal-Overa with technical implementation by CESYT, within the framework of **CLIMAAX**. It was developed to address the question of why heatwave-related climate risks must be assessed locally, and to provide answers through concrete analysis and evidence. The study addresses the increasing risks posed by **heat waves** in semi-arid Mediterranean contexts, focusing on impacts on **vulnerable population groups** and the need for evidence-based adaptation measures.

The document provides a comprehensive overview that enables readers to understand the territorial, socioeconomic, and climatic challenges of Huércal-Overa, while also detailing the analytical framework, methodological refinements, and applied tools that underpin the scientific foundations for local climate resilience strategies, evidence-based policy making, and the prioritisation of urban green infrastructure as a key tool for climate adaptation.

The **principal actions** undertaken during this phase combined **territorial, natural, socioeconomic, and climate characterisation** with the application of **CLIMAAX tools** through four analytical workflows. Each workflow corresponds to a specific methodology designed to capture different dimensions of heatwave risk:

1. Climate prediction of heat waves using the **European EuroHEAT definition**.
2. Climate prediction of heat waves using a **locally adapted definition**.
3. Risk assessment based on **historical satellite data (Landsat 8)**, integrating land surface temperature and demographic vulnerability.
4. Risk assessment based on **climate projections** under RCP 4.5 and RCP 8.5 scenarios.

The **main results** achieved confirm a clear warming trend in the municipality, with average temperatures increasing by more than 1°C in the last 50 years and precipitation decreasing to historic lows. Projections indicate a **doubling to six-fold increase in heatwave days by 2075**, depending on the emissions scenario. Risk maps identify critical hotspots in the **urban centre**, especially in the **northern, southern, and central-eastern areas**, where high population density and limited vegetation coincide. Vulnerable groups such as the elderly, children, and patients with chronic illnesses are particularly at risk.

The analysis also includes an **initial stakeholder mapping**, covering institutional, social, health, and economic actors whose involvement is crucial for designing and implementing adaptation measures, and which provides the basis for future participation.

This phase contributes to the overall CLIMAAX project by delivering a robust scientific and technical basis for future work, guiding decision-making, stakeholder engagement, and the design of long-term adaptation strategies. This deliverable also provides tested workflows, validated datasets, and evidence of how climate services can be adapted to local realities. It reinforces the CLIMAAX methodological framework with improvements developed in Huércal-Overa, demonstrates the practical application of its tools in a Mediterranean municipality, and generates knowledge transferable to other regions facing similar climate risks.

Conclusions

- Huércal-Overa faces urgent climate risks that will intensify over the coming decades.
- The municipality will increasingly experience persistent muggy conditions, leading to sustained discomfort and additional health risks.

- Vulnerabilities are concentrated in densely populated areas with scarce vegetation, making it essential to prioritise **nature-based solutions**.
- The results provide a robust evidence base to guide future participatory processes and support the co-design of adaptation strategies with local stakeholders.

1 Introduction

1.1 Background

Huércal-Overa is a municipality located in the province of **Almería, Andalusia, in southeastern Spain**. It covers an **area of 318 km²** and has a population of approximately **20,500 inhabitants**, most of whom live in the main urban centre. The town lies within the Levante Almeriense region, between the Estancias and Almagro Mountain ranges, and is crossed by the Almanzora River.

The territory is characterised by a **semi-arid Mediterranean climate**, with hot, dry summers, mild winters, and highly irregular rainfall. Natural vegetation is scarce and dominated by **scrublands and grasslands**, while agriculture (almonds, citrus, vegetables, and intensive pig farming) plays a central role in the local economy. The **Almanzora River** crosses the municipality, although water resources are limited and irregular, which adds further stress to agricultural production. Land use is dominated by crops (about 46% of the territory) and scrub-grasslands (about 37%), while forest cover is minimal, reflecting the fragile ecological balance of the area. In addition, parts of the municipality are included within the Natura 2000 Network as Special Areas of Conservation (SAC), such as the Sierra de Almagro and surrounding habitats, which highlight its ecological importance despite limited forest cover.

Socio-demographically, Huércal-Overa presents a **younger profile** compared to regional averages, but the proportion of elderly residents is increasing. Around **20% of the population is of foreign origin**, adding to the community's diversity. Despite this, unemployment remains above the national average, influencing the municipality's overall vulnerability. The municipality has experienced moderate growth in recent years, supported by migration, with the proportion of people over 65 continuing to rise (currently around 12%). This trend, combined with a younger-than-average structure, generates specific challenges for social services and increases sensitivity to extreme heat events.

Huércal-Overa's **economy is strongly linked to agriculture and livestock**, particularly almond and citrus cultivation and intensive pig farming, which rank among the most important in Spain. The municipality also plays a role as a service hub for the surrounding rural areas, with health, education, and commercial activities concentrated in the main town. Average gross income remains below the national average, while unemployment levels are higher, reinforcing its socioeconomic vulnerability.

1.2 Main objectives of the project

The LUGIA project was designed with the objective of **assessing the risks and vulnerabilities associated with climate change**, with a specific focus on the increasing **intensity and frequency of heat waves in Huércal-Overa**. The project seeks to provide a comprehensive scientific basis to support evidence-based decision-making, local adaptation planning, and the design of targeted interventions that protect vulnerable populations and critical urban functions.

More specifically, the objectives are:

- To analyse future climate scenarios for Huércal-Overa, estimating the frequency, duration, and intensity of heat waves under different emission pathways.
- To assess the risks to public health, particularly for vulnerable groups such as the elderly, children, and individuals with chronic illnesses.

- To integrate territorial, socioeconomic, and environmental information to produce risk maps that identify the most exposed areas.
- To initiate stakeholder engagement, establishing the groundwork for participatory processes in future phases of the project.

The significance of the project lies in its **capacity to generate locally relevant knowledge** and provide tools that strengthen the resilience of Huércal-Overa against climate extremes. By applying the CLIMAAX Handbook, the project benefits from a harmonised methodology that ensures comparability across European regions while allowing for local refinements and improvements. The use of the Handbook guarantees methodological robustness and facilitates the integration of climate services into municipal planning.

Expected benefits of this approach include improved identification of risk hotspots, prioritisation of adaptation actions, and the design of nature-based solutions that enhance thermal comfort and public health. Ultimately, the project aims to position Huércal-Overa as a model municipality for climate adaptation in semi-arid Mediterranean environments.

1.3 Project team

Team from Huércal-Overa Municipality

- **Baltasar Sánchez Pérez:** Graduate in Political Science and Public Administration. Holds a Master's degree in Political Theory and Democratic Culture, as well as a Master's in Teacher Training. Experienced in education as a Geography and History teacher. At the Huércal-Overa Town Hall, he currently works as Officer for Procurement, European Projects and Grants, and Youth Policy Development, managing procurement procedures, European projects, and grants.
- **Alfonso Juan Cueli Bernal:** Graduate in Agricultural Engineering. He has 27 years of experience in Local Development and in managing local, regional, national, and European grants and funding. He has worked as a Local Employment and Development Agent, a Local Promotion and Employment Agent, and currently works at the Huércal-Overa Town Hall as Technical Officer for Project Development and Coordinator of the Employment, Promotion, Trade and Transport, and Rural Development Department, where he is responsible for identifying, applying for, and managing calls for grants and incentives, as well as overseeing employment programs.

Team from CESYT

- **Juan Bautista Tomás Gabarrón:** Juan Bautista Tomás Gabarrón is a telecommunications engineer (PhD, UPCT) and co-founder of CanopyQ, an AI and satellite-based platform for urban green infrastructure management. His work applies advanced artificial intelligence to monitor vegetation health, biodiversity, CO_2 storage, and thermal comfort in real time, contributing to climate resilience and sustainable urban planning.
- **Almudena Sánchez Centeno:** holds a degree in Environmental Sciences and is a specialist in urban green infrastructure and biodiversity. At CESYT, she leads projects on cartography of urban green infrastructure strategies and the diagnosis, planning, and monitoring of nature-based solutions for climate adaptation, integrating biodiversity, ecosystem services, and climate adaptation into urban planning frameworks.

- **Antonio Ayllon:** holds a bachelor's degree in computer science and has specialized in deep learning for computer vision. At CESYT, he manages the data processing pipeline, model development & training, as well as the application backend. His work involves building cloud-based architectures that integrate satellite imagery, spectral data, and geospatial information to provide key insights for urban green infrastructure management.
- **Pablo Lorenzo Domínguez:** biologist with master's degrees in conservation and environmental management, specialized in GIS and satellite analysis applied to biodiversity and urban green infrastructure. At CESYT, he develops environmental assessment and climate adaptation projects, applying geoinformation and remote sensing tools to evaluate vegetation and ecosystem services.

1.4 Outline of the document's structure

This deliverable template is structured to provide both scientific evidence and practical guidance for decision-making.

Section 1 introduces the project background, objectives, and team, setting the context for the analysis.

Section 2 details the Phase 1 Climate Risk Assessment, including the selection of hazards, scenarios, and workflows, and presents the first results on heatwave risks and vulnerable groups.

Section 3 summarises the main conclusions, highlighting the most urgent challenges and adaptation needs.

Section 4 reviews the progress achieved and shows how the outputs of Phase 1 will directly support the refinement of assessments and the design of adaptation strategies in Phases 2 and 3.

Section 5 compiles the supporting documentation and datasets that ensure transparency and reproducibility of results.

Finally, section 6 lists the references used.

2 Climate risk assessment – phase 1

2.1 Scoping

The scoping phase establishes the foundations of the climate risk assessment by defining its objectives, the context in which it is implemented, and the main actors that must be involved. In the case of Huércal-Overa, this phase is particularly important to align the use of the CLIMAAX methodology with the municipality's local realities, ensuring that the analysis addresses the most relevant hazards—specifically heat waves—while reflecting the social, economic, and environmental vulnerabilities of the community.

2.1.1 Objectives

The **objective of this Climate Risk Assessment (CRA)** is to evaluate the **current and future risks associated with heat waves** in Huércal-Overa, focusing on their impacts on public health, the local economy, and urban systems. The **purpose** is to generate **robust, evidence-based knowledge** that can guide municipal decision-making and support the design of adaptation measures, particularly through nature-based solutions such as the expansion of urban green infrastructure. The **expected outcome** of this assessment is the **identification of critical hotspots** where population vulnerability overlaps with heat exposure, highlighting priority areas for adaptation.

The results of this CRA are intended to inform **local and regional policy frameworks**, providing direct inputs for urban planning, public health strategies, and environmental management. In particular, they will serve as the basis for redesigning the city's green infrastructure with criteria of thermal comfort and resilience against heat waves, using adapted vegetation that maximises ecosystem services such as cooling, shading, and improved public health. By aligning with the CLIMAAX methodology, the results can also contribute to broader European adaptation efforts while supporting the integration of climate resilience objectives into upcoming **local development plans**, including land-use planning and municipal health and sustainability strategies. This ensures that the outcomes are not only scientifically rigorous but also directly connected to policy processes at both the local and regional level.

This CRA acknowledges its **limitations and boundaries**. The analysis is primarily focused on **heat waves** as the main hazard and does not comprehensively cover other climate-related risks (such as floods or droughts), since the emphasis is placed on risks with a more direct and measurable impact on citizens' health. Data availability is also a constraint, particularly regarding detailed health statistics and socioeconomic variables, limiting the possibility of producing a fully comprehensive vulnerability index in this phase. Stakeholder involvement has begun with preliminary mapping, but broader participation will be developed in subsequent phases. Despite these constraints, the CRA provides a **solid first step** in building a structured, participatory, and evidence-based climate adaptation strategy for Huércal-Overa.

2.1.2 Context

Until now, **climate hazards, impacts, and risks in Huércal-Overa have been assessed mainly through regional climate studies and national platforms** such as AEMET and AdapteCCa. These sources provide valuable datasets and indicators on historical and projected temperature and precipitation trends, drought indices, and climate scenarios. However, their resolution and scope are primarily regional or national, meaning that local-scale vulnerability assessments for Huércal-Overa have been limited. As a result, their direct application to municipal planning and decision-making has been constrained.

The **problem this project addresses** is the **growing exposure of the population to heat waves**, which directly affects health, quality of life, and economic activity. This challenge is not isolated but fits within broader regional and national concerns regarding water scarcity, ecosystem degradation, and rural depopulation. Climate projections indicate that Andalusia could warm by between 2.5°C and 4.5°C by the end of the century, while Spain overall is expected to face increases of 2°C to 4°C under high-emission scenarios (RCP 8.5), according to projections from IPCC AR6, Spain's National Climate Change Adaptation Plan (PNACC), and regional analyses provided by AEMET and AdapteCCa. Huércal-Overa's case therefore highlights how local vulnerabilities intersect with systemic pressures in Andalusia and Spain, where regional warming trends are expected to be more intense than the European average.

The **governance context** is defined by European, national, and regional frameworks. At EU level, the European Green Deal and Climate Adaptation Strategy provide overarching guidance. Nationally, Spain's National Climate Change Adaptation Plan (PNACC) sets priorities, while Andalusia's regional climate and energy strategy establishes targets and actions. Locally, municipal planning instruments such as the PGOU (General Urban Development Plan) guide land use but have only recently begun to integrate climate resilience. In addition, the municipality has aligned its policies with the United Nations 2030 Agenda for Sustainable Development and has developed its own **Huércal-Overa 2030 Agenda**, which sets out local priorities and actions for sustainability. This document explicitly incorporates climate adaptation and environmental sustainability into the municipality's development commitments.

Relevant sectors for Huércal-Overa include agriculture and livestock, highly sensitive to rising temperatures and water scarcity; public health, with growing risks of hospitalisation and mortality linked to heat waves; and urban planning, where limited vegetation and high population density exacerbate exposure. Additional sectors affected include energy (due to increased demand for cooling) and employment, particularly outdoor labour in agriculture and construction. Migration dynamics are also relevant, as around 20% of the population is of foreign origin; this group can be especially affected due to socioeconomic vulnerability, housing conditions, and access to resources during extreme heat events.

Outside influences include regional and national initiatives on water management and climate adaptation, such as Andalusia's Regional Climate Action Plan and Spain's PNACC. At the provincial level, Almería has supported initiatives such as the **Plan Andaluz de Acción por el Clima (PAAC)**, research on water efficiency in greenhouse agriculture by **Fundación Cajamar**, and desertification studies led by the **Estación Experimental de Zonas Áridas (CSIC)**. Locally, projects on irrigation modernisation, small-scale urban greening pilots, and the municipality's own **Huércal-Overa 2030 Agenda** also frame the context in which climate risks are addressed, making the analysis more grounded in concrete experiences.

In the next phases, the project will explore in depth **how to mitigate the impacts of heat waves through nature-based solut**ions, focusing on the redesign of urban green infrastructure with criteria of thermal comfort and climate regulation. Special emphasis will be placed on the selection of adapted vegetation that maximises ecosystem services such as cooling, shading, and improved resilience against extreme heat.

2.1.3 Participation and risk ownership

The first steps to set up stakeholder involvement in the LUGIA project have focused on identifying institutions, organisations, and groups most affected by or able to influence climate adaptation in Huércal-Overa. A preliminary stakeholder mapping was carried out, highlighting relevant actors across government, civil society, the private sector, health services, and education. This mapping will be the basis for a reference point that will serve as the basis for future work on stakeholder coordination and participatory planning.

Relevant stakeholders include:

- **Government and institutions:** Municipality of Huércal-Overa (lead beneficiary), Civil Protection, Huércal-Overa Public Services Management (responsible for water supply and green area maintenance).
- **Health sector:** La Inmaculada Hospital, Huércal-Overa Health Centre, and associations representing patients with chronic conditions like Alzheimer or cancer.
- **Social sector:** Senior associations, neighbourhood associations, and migrant organisations
- **Education sector:** Schools, representing children, one of the most vulnerable groups.
- **Private sector and agriculture:** Irrigation communities, agricultural cooperatives, and companies engaged in intensive pig farming, a key economic sector highly exposed to climate stress.

Priority groups identified are elderly citizens, children, people with chronic illnesses or disabilities, and low-income populations living in vulnerable housing conditions. These groups require special consideration in both analysis and adaptation planning.

Risk ownership is formally regulated through municipal responsibilities, supported by regional and national frameworks such as Spain's PNACC and Andalusia's Regional Climate Strategy. The municipality has the mandate to coordinate risk management at the local level, particularly in relation to public health, urban planning, and emergency response.

In terms of **acceptable risk**, the community's tolerance for climate-related impacts is low when it comes to health and safety. Heat-related hospitalisations and mortality observed in recent years underline the urgency of reducing exposure to extreme heat, meaning that adaptation goals aim for significant risk reduction rather than acceptance of current levels.

Communication of results will be carried out through municipal channels (public consultations, council meetings, and the official website), stakeholder workshops, and targeted engagement with vulnerable groups through associations and NGOs. Results will also be shared with regional and national institutions to ensure alignment with wider adaptation strategies and to facilitate funding opportunities.

2.2 Risk Exploration

The risk exploration phase provides an **initial screening of climate-related risks in Huércal-Overa**, focusing on the hazards, exposures, and vulnerabilities that are most visible and of greatest concern to both stakeholders and the wider public.

2.2.1 Screen risks (selection of main hazards)

In Huércal-Overa, the most relevant climate-related hazards are **extreme heat and recurrent heat waves**. Over the past five decades, the municipality has already experienced an increase of more than 1°C in average annual temperature, a decline in rainfall, and a marked rise in the number of warm days and tropical nights. **These conditions are most evident in the urban centre**, where high population density, limited vegetation, and the concentration of critical facilities such as schools, health centres, and senior residences make the impacts of heat especially severe. Residents in these areas are exposed to higher land surface temperatures and reduced night-time cooling, which intensifies health risks.

According to the **Copernicus Climate Atlas**, southern Spain, including Andalusia, will face **substantial warming in the coming decades**. The Atlas projects an increase of between 2.5°C and 4.5°C in average annual temperature by the end of the century under high-emission scenarios, accompanied by more frequent and longer-lasting heat waves. It also indicates that maximum summer temperatures above 40°C will become increasingly common, and periods of high heat stress will expand significantly. Drought conditions are also expected to intensify due to reduced and irregular rainfall, with implications for water availability and agriculture. This trend reinforces what has already been observed locally and confirms that heat waves, alongside worsening drought, will intensify as defining climate hazards for the region.

This **Climate Risk Assessment therefore focuses on heat waves as the primary hazard**. The decision to prioritise them comes from their **direct and measurable effects on public health**, especially among vulnerable groups such as the elderly, children, and people with chronic illnesses. Other risks, such as drought and flooding, are acknowledged as relevant at the regional scale, but their local impacts are less immediate compared with the urgent challenge presented by heat extremes in Huércal-Overa.

The analysis relies on data from **AEMET climate records**, **EURO-CORDEX projections**, and the **Copernicus Climate Data Store**, complemented by **satellite-derived land surface temperature** (Landsat 8) and **demographic information from INE, WorldPop, and municipal sources**. Nevertheless, gaps remain in detailed health datasets and fine-scale socioeconomic indicators, which will need to be addressed in future phases of the project to strengthen vulnerability assessments.

2.2.2 Workflow selection

Based on the identification of heatwaves as the main climate hazard for Huércal-Overa, four specific workflows were selected to structure the risk assessment. Each workflow integrates methodological approaches to capture exposure, vulnerability, and spatial distribution of risk.

2.2.2.1 **Workflow 1: Heatwaves – EU-EuroHEAT definition:** This workflow applies the EuroHEAT methodology, using standardized health thresholds to identify and characterize heatwave events at the European scale.

2.2.2.2 **Workflow 2: Heatwaves – Local definition:** This workflow introduces a tailored definition for Huércal-Overa, establishing a locally relevant threshold for heatwaves to better reflect health risks and climatic conditions.

2.2.2.3 **Workflow 3: Risk assessment with historical satellite data:** This workflow combines satellite-based surface temperature data with demographic information to assess spatial patterns of exposure and vulnerability in past extreme heat events.

2.2.2.4 **Workflow 4: Risk assessment with climate projections:** This workflow employs climate model projections to estimate the evolution of future heatwave risk under different emissions scenarios, integrating demographic data to highlight vulnerable areas.

Together, these workflows provide a coherent methodological framework to evaluate current and future climate risks in Huércal-Overa

2.2.3 Choose Scenario

The selection of relevant scenarios is essential to contextualize the climate risk assessment for Huércal-Overa. Assumptions considered for the municipality include both climatic and socio-economic dimensions. Climatically, the region is expected to experience progressive warming, longer and more intense heatwaves, and a continued reduction in precipitation, consistent with semi-arid Mediterranean dynamics. Socio-economic developments include moderate population growth, a steady ageing trend, the persistence of migration flows, and the importance of agriculture and livestock as key economic activities, all which condition vulnerability to climate risks.

For analytical consistency, three-time perspectives are considered:

- **Short-term (next 5 years):** Incremental warming and recurrent heat events with immediate health and energy implications.
- **Medium-term (20–30 years):** Noticeable intensification of heatwave frequency and duration, combined with demographic ageing and growing pressure on water and land use. This perspective broadly aligns with the **near-future horizon (2016–2045)** used in the workflows.
- **Long-term (50–100 years):** Strong divergence between mitigation and high-emission trajectories, with very frequent and severe heatwaves expected, affecting agriculture, urban systems, and economic productivity. This corresponds to the **distant-future horizon (2046–2075)** analysed in the workflows.

Within the workflows applied in this project, the most relevant scenarios are those based on EURO-CORDEX projections under **RCP 4.5 (moderate mitigation) and RCP 8.5 (high emissions)**. These provide a consistent framework to assess both intermediate and extreme warming trajectories for Huércal-Overa, while integrating demographic and socio-economic conditions.

2.3 Risk Analysis

2.3.1 Workflow 1: Heatwaves – EU-EuroHEAT definition

Within the workflows applied in this project, the most relevant scenarios are those based on EURO-CORDEX projections under **RCP 4.5 (moderate mitigation) and RCP 8.5 (high emissions)**. These provide a consistent framework to assess both intermediate and extreme warming trajectories for Huércal-Overa, while integrating demographic and socio-economic conditions.

Table 2-1 Data overview workflow #1

Hazard data	*Risk output*
CDS sis-heat-and-cold-spells, health definition (HWD_EU_health_rcp45/85)	Bar charts of heat-wave days per year (RCP4.5 vs RCP8.5)

2.3.1.1 Hazard assessment

The hazard addressed in this workflow is the **occurrence of heatwaves, defined according to the EuroHEAT** methodology as periods of at least two consecutive days during which both maximum and minimum apparent temperatures exceed the 90th percentile of the reference climatology (1971–2000). This standardized definition ensures comparability with European health-related studies and provides a robust basis for identifying extreme heat events in Huércal-Overa.

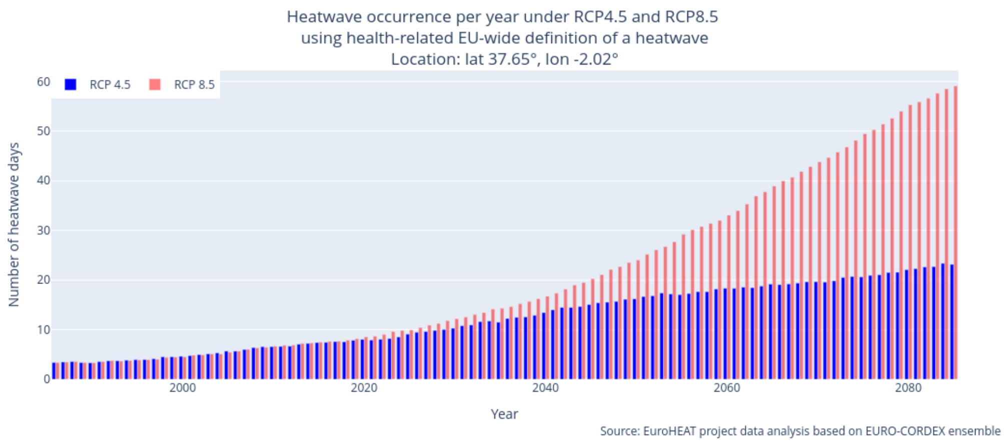

Figure 2-1 Heat wave days per year (RCP 4.5 vs. RCP 8.5, EU definition)

Figure source: EuroHEAT (analysis with EURO-CORDEX ensemble). Prepared by the authors.

Results indicate that, under this definition, **the municipality currently experiences around 10 heatwave days per year**, already more than five days above the situation in 2000. Projections reveal a clear upward trend, with heatwave days expected to **double under RCP 4.5 and triple under RCP 8.5 by the middle of the century**. This confirms heatwaves as the primary climatic hazard for Huércal-Overa.

2.3.1.2 Risk assessment

The **increase in heatwave frequency and duration** identified in Huércal-Overa represents a **critical risk to public health and well-being**. With heatwave days already exceeding historical levels, the population is increasingly exposed to episodes of extreme heat that can trigger heat stress, dehydration, and a higher incidence of cardiovascular and respiratory complications.

Projections indicate that heatwave days will double under RCP 4.5 and triple under RCP 8.5 by mid-century compared to present conditions. This escalation significantly **increases the probability of excess mortality and hospital admissions during extreme events**, particularly as prolonged periods of high minimum temperatures reduce nighttime recovery capacity.

These trends confirm that **heatwaves are not only a recurrent climatic hazard** but also a major risk factor for human health in Huércal-Overa. Without effective adaptation measures, the compounding effect of longer and more intense heatwaves could increase pressure on healthcare systems and challenge community resilience, positioning heatwaves as the most pressing climate-related risk for the municipality.

2.3.2 Workflow 2: Heatwaves – Local definition

Table 2-2 Data overview workflow #2

Hazard data	*Risk output*
EURO-CORDEX tasmax/tasmin historical + RCP4.5/8.5	Heatwave Index RCP4.5/8.5 projections (Bar charts + linear fits)
EURO-CORDEX tasmax/tasmin historical + RCP4.5/8.5	Heatwave Frequency RCP4.5/8.5 projections (Bar charts + linear fits)
EURO-CORDEX tasmax/tasmin historical + RCP4.5/8.5	Mean Heatwave Event Duration RCP4.5/8.5 projections (Bar charts + linear fits)
EURO-CORDEX tasmax/tasmin historical + RCP4.5/8.5	Rothfusz Heat Index Value RCP4.5/8.5 projections (Bar charts + linear fits)

2.3.2.1 Hazard assessment

This workflow applies a locally adapted definition of heatwaves for Huércal-Overa: periods of at least three consecutive days with maximum daily temperatures above 35 °C. This threshold reflects local climatic conditions and documented health impacts. Analysis of EURO-CORDEX projections under RCP 4.5 and RCP 8.5 shows that Huércal-Overa currently experiences about 10 such days per year. By 2060, this number is projected to increase to 15–20 days under RCP 4.5 and more than 20 days under RCP 8.5, with extreme years reaching 30–40 days per year.

The indicators analysed in this workflow provide complementary perspectives on the evolution of extreme heat:

- **Total number of days in heat waves**: counts the cumulative days per year that meet the heatwave threshold. This rises from around 10 historically to more than 20 by 2060 under RCP 8.5.

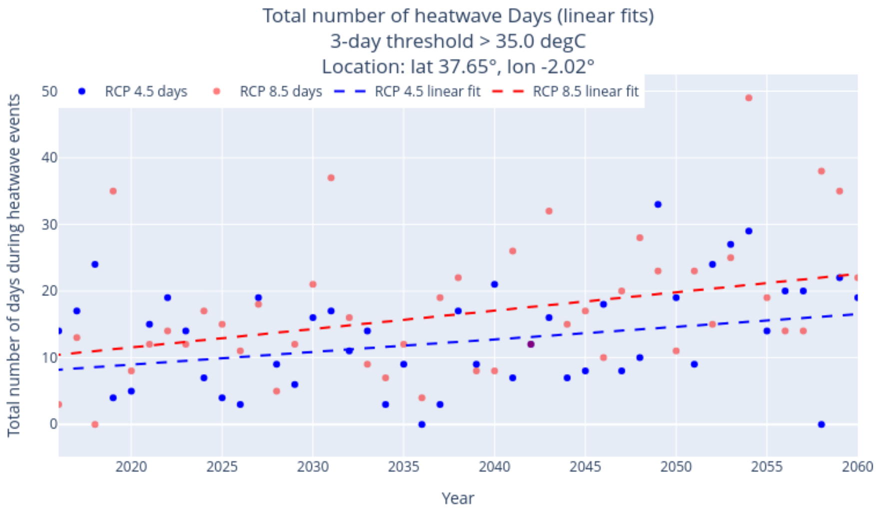

Figure 2-2 Total days in heat waves: annual trend (RCP 4.5 vs. RCP 8.5). Annual dispersion and linear fit lines

Figure source: GCM–RCM indicated. Prepared by the authors.

- **Average annual duration per heatwave event**: measures the mean length of each episode. It increases from less than 3 days historically to nearly 6 days, with extreme years exceeding 8 days.
- **Annual frequency of heat waves**: indicates how many distinct heatwave events occur per year. This doubles from about 2 events per year to approximately 4 events, with peak years exceeding 6 or 7.

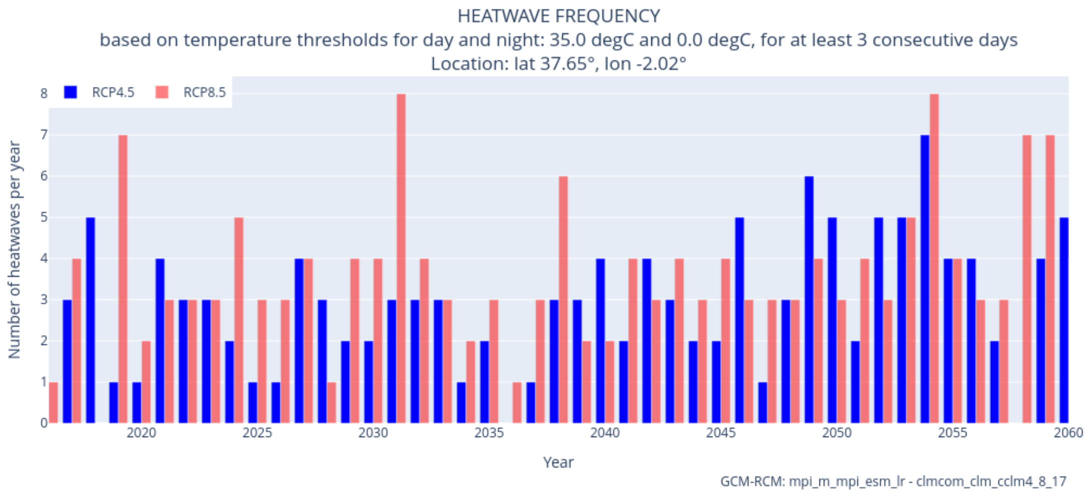

Figure 2-3 Heat wave frequency: annual bars (RCP 4.5 vs. RCP 8.5).

Figure source: GCM–RCM indicated. Prepared by the authors.

- **Heat-Wave Index (cumulative days per year)**: represents total annual exposure, meaning the sum of all days per year that fall within heatwave periods and therefore indicate the overall level of population exposure to extreme heat. Currently just above 5 days per year, it exceeds 15–20 days by 2040 under RCP 8.5 and occasionally 30 days per year.
- **Rothfusz Heat Index (HI)**: combines temperature and humidity to estimate perceived heat stress. Historical average values are above 27 °C, projected to approach 28 °C under RCP 4.5 and exceed 29 °C under RCP 8.5 by 2060. This indicates persistent discomfort, though not reaching the 32 °C threshold for critical stress.

2.3.2.2 Risk assessment

The projected intensification of heatwaves defined at the local threshold has clear implications for Huércal-Overa. As highlighted in the hazard assessment, the expected increase in total days, average duration, frequency, and cumulative exposure will sustain **thermal discomfort and aggravate health risks**. These include dehydration, cardiovascular stress, and hospital admissions, disproportionately affecting vulnerable groups such as the elderly, children, and people with chronic illnesses (MoMo, Instituto de Salud Carlos III, 2024).

At the urban scale, the longer and more frequent heatwave episodes described in the hazard assessment are expected to amplify **the urban heat island effect**, reduce night-time cooling, and increase energy demand for cooling systems, raising household and municipal costs. Without intervention, such conditions could lead to deteriorating public health, reduced quality of life, and escalating economic losses (IPCC, 2021).

In line with the overall findings, and consistent with the evidence from the hazard indicators, **expanding and strengthening green infrastructure** is identified as a **priority adaptation strategy** to mitigate the risks projected under both moderate and high emission scenarios.

2.3.3 Workflow 3: Risk assessment with historical satellite data

Table 2-3. Data overview workflow #3

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
Landsat-8 LST biweekly raster data JUN-AUG 2016			Overheating maps (municipality & urban)
	INE 2024 vulnerable population data	INE 2024 population density and total population data	INE total population and vulnerable population density maps + vulnerability class distribution pie charts
	WorldPop vulnerable population data	WorldPop population density data	WorldPop total population and vulnerable population density maps + vulnerability class distribution pie charts
	INE total population and vulnerable population density maps	Landsat-8 LST biweekly raster data JUN-AUG 2016	Composite 5-class risk level map (INE)
	WorldPop total population and vulnerable population density maps	Landsat-8 LST biweekly raster data JUN-AUG 2016	Composite 5-class risk level map (WorldPop)
	Composite 5-class risk level map (WorldPop) + georeferenced Huércal-Overa criical infrastructure data		Possible heat risk level to vulnerable population map highlighting green elements and common urban spaces

2.3.3.1 Hazard assessment

The assessment was therefore conducted at two spatial scales: the entire municipality, which comprises multiple localities, and the central urban area, where population density is significantly higher. This distinction was necessary to properly capture and understand the spatial dynamics of heatwave exposure and vulnerability.

This workflow uses Landsat-8 satellite data (summer 2016, the hottest year in the series) to assess surface thermal exposure in Huércal-Overa. Land Surface Temperature (LST) was mapped at 30 m resolution and classified into ten categories of overheating risk. Results indicate that the municipality shows marked spatial variability: the central and northern areas, particularly the densely built-up urban areas, recorded the highest surface temperatures, while southern and eastern sectors remained cooler due to vegetation cover and proximity to the Almanzora River. Overall, **12.8% of the**

municipal area falls into "very high" thermal risk categories, with the urban core of Huércal-Overa entirely within zones of elevated heat exposure.

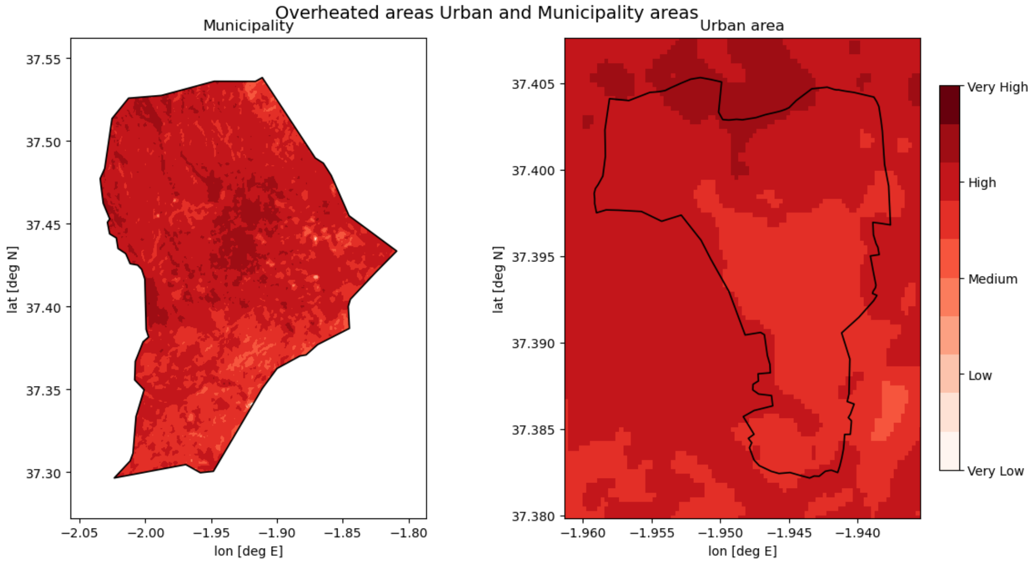

Figure 2-4 Overheated zones (exposure) in urban and municipal areas.

Figure source: Landsat-8 OLI/TIRS (2016). Prepared by the authors.

2.3.3.2 Risk assessment

By combining LST data with demographic information (WorldPop and INE), the analysis identifies clear hotspots where thermal exposure coincides with vulnerable population groups (children aged 0–4 and adults aged 65+). In line with the CLIMAAX methodology, WorldPop is used as the primary reference source, while complementary INE data are incorporated through their aggregation procedures to refine estimates and enable integration of additional variables in later phases. According to INE 2024 data, **over 21% of the municipality's population** lives in areas with high vulnerability, with the urban centre concentrating the majority. WorldPop estimates corroborate this, showing that the town of Huércal-Overa, which represents only **1.4% of the municipal territory**, contains the largest share of vulnerable residents.

Risk is highest in the **urban centre**, especially in the northern and southern sections, where dense residential areas overlap with elevated surface temperatures. Specific critical locations include areas around **La Molineta, Hospital de la Inmaculada, and Príncipe Felipe Primary School**, as well as the central-east corridor near the employment office and **Adolfo Suárez Park.** Within these zones, densities of vulnerable population exceed **9% of residents**, underlining the concentration of risk in compact neighbourhoods.

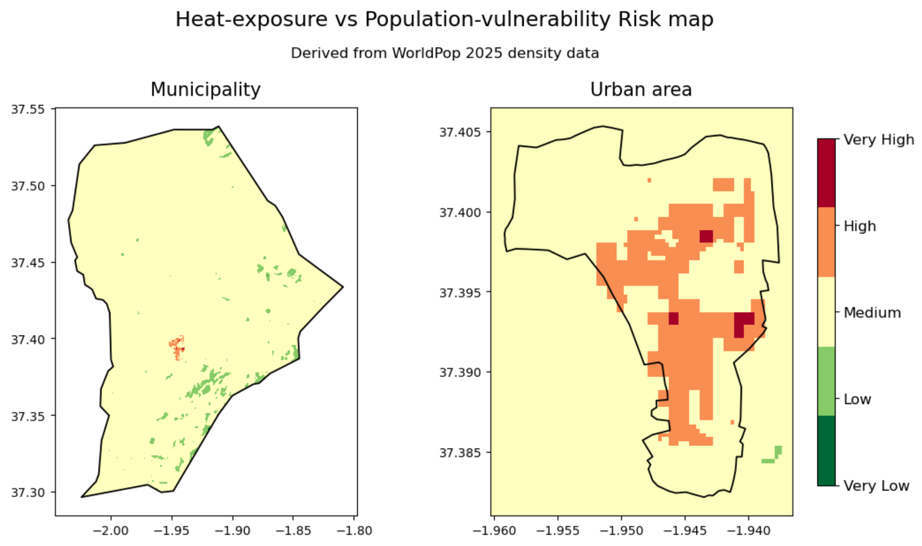

Figure 2-5 Risk map: Result of the risk matrix (exposure × vulnerability) grouped into five levels.

Figure source: Landsat-8 OLI/TIRS (2016); WorldPop 2025. Prepared by the authors.

The conclusions highlight that climate risk in Huércal-Overa is spatially concentrated, with vulnerability amplified by limited vegetation cover in high-density districts. Without adaptation, these zones are likely to experience disproportionate impacts during extreme heat events.

2.3.4 Workflow 4: Risk assessment with climate projections

Table 2-4 Data overview workflow #4

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
CDS sis-heat-and-cold-spells EU health definition (RCP4.5/8.5)			Relative change in yearly Heatwave days vs 1986-2015 baseline + reclassified relative change in yearly Heatwave days vs 1986-2015 baseline
	WorldPop vulnerable population density classified raster	Reclassified relative change in yearly Heatwave days vs 1986–2015 baseline maps	Relative change of Heatwave risk to vulnerable population groups (Municipality + Urban Area maps) - WorldPop source
	INE vulnerable population density classified map	Reclassified relative change in yearly Heatwave days vs 1986–2015 baseline maps	Relative change of Heatwave risk to vulnerable population groups (Municipality + Urban Area maps) - INE source

2.3.4.1 Hazard assessment

This workflow uses EURO-CORDEX climate projections under RCP 4.5 and RCP 8.5 to assess future changes in heatwave occurrence in Huércal-Overa, using the EuroHEAT definition as reference. The baseline (1986–2015) was compared to near-future (2016–2045) and distant-future (2046–2075) periods. Results show a marked increase in the relative number of heatwave days.

Under **RCP 4.5**, projections indicate a **150% increase in heatwave days by 2016–2045**, and u**p to 300% by 2046–2075** in the most sensitive areas. Under **RCP 8.5**, the increase is more severe, with around **200% more heatwave days by 2016–2045 and values exceeding 600% by 2046–2075** across much of the municipality. Spatially, the southern and eastern sectors, currently cooler, are expected to experience proportionally larger increases in heatwave frequency.

These projections confirm a **strong escalation in thermal hazard** over the coming decades, with frequency, duration, and intensity of heatwaves all increasing substantially compared to historical conditions.

2.3.4.2 Risk assessment

When demographic vulnerability is integrated (WorldPop as the main reference, complemented by INE data), results show that risk is strongly concentrated in the **urban core of Huércal-Overa**, where high population densities coincide with projected thermal stress.

According to WorldPop, risk levels in the central-eastern corridor between the employment office and Adolfo Suárez Park are projected to reach high under RCP 4.5 and very high under RCP 8.5 by 2046–2075. The INE-based analysis confirms this pattern, identifying the southern and central sectors as areas of greatest vulnerability**,** while the northern area maintains comparatively moderate risk. In both datasets, the **urban centre and southeastern municipality emerge as critical hotspots**, with risk levels rising from moderate today to very high in the distant-future horizon under RCP 8.5.

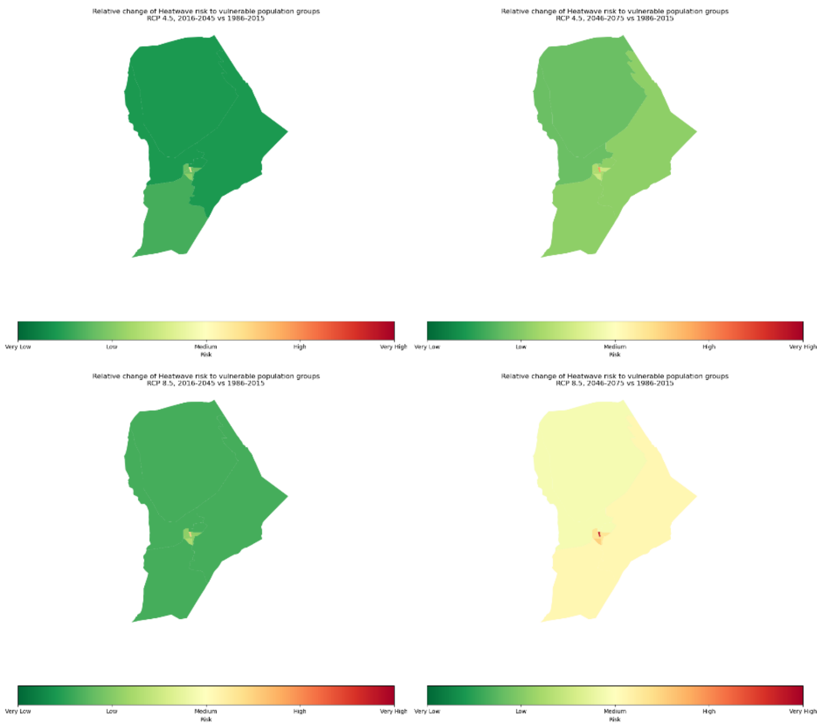

Figure 2-6 Risk map: Future risk (municipality) using INE vulnerability.

Figure source: Climate projections (RCP 4.5/8.5); INE (2024). Prepared by the authors.

The conclusions emphasise that **without adaptation, Huércal-Overa will face severe impacts** on public health, and urban liveability, especially in compact neighbourhoods with limited vegetation. This highlights the urgency of prioritising nature-based solutions, particularly urban greening and shading strategies, to mitigate future risks where exposure and vulnerability most clearly overlap.

2.4 Preliminary Key Risk Assessment Findings

2.4.1 Severity

Heatwaves represent a **high-severity climate risk** for Huércal-Overa. Considering historical and current trends, average annual temperatures have already risen by more than 1 °C in the last 50 years, with warm days and tropical nights doubling. Projections indicate that heatwave days could increase by up to 600% under RCP 8.5 by 2075.

In this context, the **climate risk is clearly high both in impact and in frequency**. It leads to excess mortality, higher hospital admissions, and health complications among vulnerable groups. These outcomes have direct consequences for public health and indirect impacts on the economy through rising healthcare costs. For example, national estimates indicate that heatwaves can increase hospital admissions by 3–8% (Carlos III Health Institute, MoMo, 2024) during summer periods, generating additional health costs that put further pressure on municipal and regional budgets.

The risk also extends to major sectors of the municipality. Agriculture and livestock face production losses and increased water demand, while local commerce and services are challenged by reduced productivity and higher operating costs. These impacts translate into significant financial consequences for households, municipal budgets, and the regional economy.

Beyond these direct and indirect effects, persistent extreme heat can trigger cascading impacts such as higher energy demand, labour constraints, and stress on urban systems. In the longer term, it may aggravate environmental degradation, biodiversity loss, and the reduction of agricultural land. Taken together, **these dynamics highlight the possibility of irreversible consequences if unaddressed.**

2.4.2 Urgency

The urgency of **addressing heatwave risk in Huércal-Overa is high and immediate**. Projections for the near future (2016–2045) already indicate a doubling or tripling of heatwave days compared to the baseline, meaning that the impacts will become major within the next two decades. To minimise damages, action needs to be taken immediately, with priority in the short term.

Unlike gradual-onset processes such as sea level rise, **heatwaves are sudden and acute events**, with immediate consequences for health and quality of life. This characteristic strongly influences their urgency scoring, since even short episodes can generate severe impacts. Their persistence across consecutive days, combined with rising nighttime minimums, reduces recovery capacity and heightens short-term mortality risks. This confirms that the hazard is expected to worsen significantly soon.

At the same time, heatwaves are not isolated episodes but **persistent and recurrent phenomena** throughout summer periods. This persistence means the hazard has the potential to continue and even intensify over time, reinforcing its urgency. Therefore, preventive action is required in the short term, particularly to protect vulnerable populations and avoid escalating health and economic costs.

2.4.3 Capacity

The municipality currently has a **moderate but developing adaptive capacity** to cope with increasing heatwave risks. Existing measures include alignment with the Spanish PNACC, Andalusia's regional climate strategy, and the municipal 2030 Agenda. The Huércal-Overa 2030 Agenda explicitly recognises climate adaptation and sustainability as strategic priorities, highlighting actions such as expanding green infrastructure, improving energy efficiency, and strengthening social cohesion. Forecasting and warning systems are also available through AEMET and MoMo, and health institutions together with civil protection services have begun to engage in awareness and preparedness activities.

Nevertheless, important challenges remain. Financial resources are limited, which constrains the scope of new investments. Natural capacity is modest due to scarce green infrastructure, which reduces the regulation of heat. Human and social capacity are still consolidating, as local associations and institutions require stronger coordination and resources. Physical capacity, while supported by forecasting tools, is not yet fully integrated into municipal planning.

Specific interventions are planned, such as greening projects and efficiency improvements under the 2030 Agenda, but additional structural measures will be necessary. Huércal-Overa would benefit from **greater financial support, stronger social and institutional coordination, technical resources, and ecosystem-based measures** to further reduce vulnerability and strengthen resilience.

2.5 Preliminary Monitoring and Evaluation

The first phase of the climate risk assessment has provided several important lessons. The application of the four workflows confirmed that heatwaves are the most relevant hazard for Huércal-Overa and allowed the identification of critical hotspots of vulnerability in the urban centre. The process also demonstrated the value of combining European datasets (EURO-CORDEX, CDS) with local demographic and socioeconomic information (INE, municipal sources), which improved the accuracy of results and their relevance for local decision-making.

Difficulties were mainly linked to **data availability and integration**. Detailed health statistics at the municipal scale remain limited, making it difficult to quantify direct impacts such as morbidity or mortality with precision. Similarly, socioeconomic data require aggregation procedures to be combined with WorldPop, the reference dataset under CLIMAAX. In this process, INE demographic data were used as a complementary source, ensuring that local statistics could be integrated through their aggregation methodology. This added complexity but also revealed the importance of methodological consistency when aligning local data with European frameworks.

Stakeholder engagement in this phase was primarily exploratory. Initial mapping identified key actors from the health sector, municipal services, civil protection, senior associations, and schools. No direct feedback was collected from stakeholders in this phase, as engagement was mainly limited to initial mapping. Broader participation and structured feedback are planned for the next phase.

In terms of monitoring and future needs, new data sources are becoming available. The expansion of INE demographic datasets and other municipal records provide opportunities to refine vulnerability and exposure assessments. Additional competencies will be required in **health impact modelling, spatial planning, and social vulnerability analysis** to deepen the assessment. Further research is also needed to explore adaptation pathways, particularly the role of urban greening and water-efficient agriculture as part of the long-term response strategy.

2.6 Work plan

The next phases of the project will follow the three-step methodology already defined in the CLIMAAX framework, ensuring consistency with the initial assessment.

Phase 1 – Application of the CLIMAAX framework (completed): This first stage involved the search and analysis of European climate datasets, integration of exposure and vulnerability data, and the implementation of harmonised workflows for heatwave risk analysis. It provided a robust baseline of hazard and risk conditions at NUTS2/NUTS3 and municipal scale.

Phase 2 – Refinement with local data (upcoming): In this phase, the analysis will be refined by integrating detailed local and regional datasets. The objective is to improve accuracy and local relevance.

Main tasks will include:

- Carrying out a joint analysis of Land Surface Temperatures (LST) with land use data to identify which urban and territorial typologies contribute most to heat generation.
- Developing a composite vulnerability index that incorporates additional variables beyond age, such as income per capita, household income and other socioeconomic indicators.
- Integrating public health data (e.g., hospitalisations, emergency visits, or heat-related mortality) to directly evaluate the health impact of extreme heat events.
- Analysing the capacity of current Urban Green Infrastructure to mitigate climate risks
    - Identifying and georeferencing the urban tree canopy, creating an updated inventory of existing vegetation.
    - Classifying tree species and determining vegetation structural variables such as canopy cover, biomass and leaf area.
    - Evaluating the capacity of Urban Green Infrastructure to improve thermal comfort and radiative balance in the municipality.
    - Analysing the adaptability of urban vegetation to climate change, considering resilience and long-term management needs.
- Producing specific cartography of urban thermal exposure, including shade maps, pavement types, permeability and other factors influencing heat accumulation.
- Initiating a process of contact with stakeholders identified in Phase 1 to collect qualitative and contextual information that will help refine and align results with the social and institutional reality of the municipality.

Phase 3 – Development of local adaptation strategies (upcoming): In this phase, the municipality will build on the refined risk assessment to design adaptation strategies focused on reducing the impacts of heatwaves. The objective is to develop locally relevant and effective solutions. Main tasks will include:

- Designing adaptation strategies with emphasis on nature-based solutions such as shaded green corridors, planting of adapted tree species, and the redesign of parks and urban areas for improved thermal comfort.
- Preparing policy recommendations and carrying out communication activities to raise awareness and ensure dissemination.
- Co-designing measures with local stakeholders to secure social acceptance and maximise effectiveness.
- Establishing a monitoring protocol with periodic updates of risk indicators, ensuring that results can be incorporated into the Huércal-Overa 2030 Agenda and other strategies.

Scope and boundaries

The work plan will concentrate on heatwave-related risks and their impact on vulnerable groups, which are considered the most immediate and measurable threat in Huércal-Overa. Other hazards such as floods or droughts are acknowledged but will not be the focus of this assessment, as their analysis would require additional data, resources, and time and they are not the specific objective of this project.

3 Conclusions Phase 1- Climate risk assessment

Main conclusions (challenges addressed and not addressed)

The first phase of the LUGIA project confirms that **heatwaves are the most critical climate-related risk** for Huércal-Overa. The analysis demonstrated that the municipality already faces a **significant increase in the number of heatwave days** compared to historical conditions, and that these events will become more frequent, longer, and more intense in the coming decades. This results in **persistent muggy conditions**, intensifying thermal discomfort and aggravating health risks, particularly among **vulnerable groups** such as the elderly, children, and people with chronic illnesses. In addition to health consequences, recurrent heatwaves are expected to put pressure on the **local economy**, increasing energy demand for cooling, reducing productivity, and generating **higher healthcare costs**.

At the same time, the results show that **vulnerabilities are geographically concentrated in the urban centre**, where high population density coincides with scarce vegetation. This combination amplifies the **urban heat island effect** and places pressure on public health and social systems. **Nature-based solutions** emerge as a central priority for climate adaptation, with urban greening, shading interventions, and the redesign of public spaces identified as effective strategies to mitigate heat stress.

This first phase provided a **robust scientific and technical evidence base** to inform local adaptation. The findings not only support the integration of climate resilience into the **Huércal-Overa 2030 Agenda** but also serve as a reference for participatory processes in upcoming phases, where stakeholder engagement will be critical to co-designing and implementing effective measures. **Limitations remain** regarding health datasets, socioeconomic indicators at fine spatial scales, and long-term monitoring frameworks, which will need to be addressed in future phases to strengthen the risk assessment.

Key findings

- **Heatwaves are the most pressing climate-related hazard** in Huércal-Overa.
- The **number, frequency, and duration of heatwave days are projected to increase substantially**, with up to a 600% rise by 2075 under RCP 8.5 (from around 10 days/year at present to more than 60 days/year). Under RCP 4.5, heatwave days are expected to double by mid-century.
- **Vulnerabilities are concentrated in the urban centre**, where more than 20% of the population lives in areas with high exposure and limited vegetation.
- **Persistent muggy conditions**, with night-time minimums frequently above 25 °C, will create sustained discomfort and health risks, especially for vulnerable groups.
- **Nature-based solutions such as expanded green infrastructure** and shading strategies are identified as the most effective pathway to mitigate projected risks, with the potential to reduce surface temperatures locally by 2–4 °C.
- Data gaps in health and socioeconomic indicators, including hospital admissions and detailed household income data, remain a challenge for future phases.

4 Progress evaluation and contribution to future phases

Phase 1 of the project successfully applied the CLIMAAX framework to Huércal-Overa, using European datasets and harmonised workflows to assess the hazard and risk of heatwaves. This phase confirmed that heatwaves are the most critical climate-related risk for the municipality, provided baseline indicators of hazard, risk and vulnerability, and identified the main hotspots of exposure. It also highlighted key challenges, including data gaps in health and socioeconomic indicators at local scale, and the need for more refined vegetation and land use data. These results provide a robust evidence base to guide Phase 2 and Phase 3.

In line with the Individual Following Plan, **Phase 1 was oriented to establish the baseline hazard and risk assessment for Huércal-Overa**. The key actions executed were:

- **Search and analysis of European climate datasets** (EURO-CORDEX, CDS).
- **Integration of exposure and vulnerability data** at NUTS2/NUTS3 and municipal scale.
- **Implementation of the four CLIMAAX workflows** (EuroHEAT definition, local threshold definition, satellite-based risk assessment, climate projections).
- Identification of **vulnerable hotspots** in the urban centre, northern and southern sectors.
- Detection of **key data gaps** (health datasets, socioeconomic indicators, vegetation structure).

These actions enabled the achievement of the KPIs and Milestones presented in the summary tables below and provide the evidence base for the refinement with local data in Phase 2.

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
Establish baseline hazard and risk assessment	Completed with European datasets and four workflows
Identify vulnerable hotspots	Achieved (urban center, north and south sectors)
Highlight key data gaps	Identified gaps in health, socioeconomic and vegetation data
Provide evidence base for Phase 2	Established

Table 4-2 Overview milestones

Milestones	*Progress*
Completion of Phase 1 hazard and risk assessment	Achieved
Identification of vulnerable hotspots	Achieved
Identification of key data gaps	Achieved
Preparation for Phase 2 refinement	Ongoing
Planning of stakeholder workshops	Upcoming

Finally, following table illustrates how the outputs of this deliverable provide the foundation for the planned activities in Phases 2 and 3, ensuring continuity and alignment across the different stages of the project.

Table 4-3 Contribution of Phase 1 to other phases

Contribution area	How Phase 1 supports Phase 2	How Phase 1 supports Phase 3
Hazard analysis	Provides baseline projections of heatwave frequency and intensity.	Identifies priority hazards (heatwaves) to address with adaptation.
Risk and vulnerability	Maps hotspots of exposure and initial vulnerable groups.	Highlights the areas and groups most in need of adaptation strategies.
Data needs	Identifies gaps in health, socioeconomic, and vegetation data.	Defines the type of local data needed to design nature-based solutions.
Methodological basis	Tests four workflows that will be refined with local datasets.	Provides evidence base to evaluate effectiveness of adaptation actions.
Stakeholder relevance	Highlights the importance of vulnerable groups (elderly, children, chronically ill).	Provides basis for stakeholder engagement in co-designing solutions.

Phase 1 has set the basis for a coherent and continuous workflow, ensuring that subsequent phases can build on robust evidence rather than starting from scratch. Its main contribution lies in clarifying priorities, identifying critical data needs, and validating the methodological approach, all of which provide direction for the refinement with local information in Phase 2 and the design of effective adaptation measures in Phase 3.

5 Supporting documentation

1. **Main report (pdf)**
2. **Visual outputs**
   - General Information About Huércal-Overa
     - Figure 4.1
     - Figure 4.2
     - Figure 4.3
     - Figure 4.4
     - Figure 4.5
     - Figure 4.6
     - Figure 4.7
     - Figure 4.8
     - Figure 4.9
     - Figure 4.10
     - Figure 4.11
     - Figure 4.12
     - Figure 4.13
     - Figure 4.14
     - Figure 4.15
   - Hazard Assessment Euroheat
     - Euroheat.png
     - quad_fits.png
   - Hazard Assessment Xclim local and UTCI
     - HI_bars.png
     - HW_days.png
     - HW_duration.png
     - HW_freq.png
     - HW_index.png
     - Regressions
     - HI_fits.png
     - HW_days_fits.png
     - HW_duration_fits.png
     - hw_freq_fits.png
     - HW_index_fits.png
   - Risk assessment LandSat
     - census_density_shares.png
     - census_total_population.png
     - census_vulnerable_density.png
     - census_vuln_poop_percentages.png
     - landsat_datapoints.png
     - landsat_stack_urban_municipality.png
     - munic_temp_vs_pop.png
     - overheat_area_shares.png
     - Riskmat.png
     - risk_munic_urban_census.png
     - risk_munic_urban_census_satellite.png
     - risk_munic_urban.png
     - risk_urban_census_green_areas.png
     - total_population_municipality_a0.png
     - total_population_urban_a05.png
     - total_population_urban_a0.png
     - urban_temp_vs_pop.png
     - vulnerable_population_full_new.png
     - vulnerable_population_full.png
     - vulnerable_population_municipality_a0.png
     - vulnerable_population_urban_a05.png
     - vulnerable_population_urban_a0.png
     - worldpop_density.png
     - worldpop_density_shares.png
   - Risk assessment projections
     - Aois.png
     - munic_change_decile.png
     - munic_change.png
     - munic_pop.png
     - risk_census_munic.png
     - risk_census_urban.png
     - risk_worldpop_munic.png
     - risk_worldpop_urban.png
3. **Communication Outputs**
   - Local press news – Click here
4. **Datasets collected**
   - General Information About Huércal-Overa:
     a. **Hydrography**: IGR_HI_v1_ES060_Cuencas_Mediterraneas_Andaluzas.gpk, IGR_HI_v1_ES070_Segura.gpkg
     b. **Municipal boundary**: Municipal boundary.cpg, Municipal boundary.dbf, Municipal boundary.prj, Municipal boundary.qmd, Municipal boundary.shp, Municipal boundary.shx
     c. **Natural environment**: Es_Lic_SCI_Zepa_SPA_Medalpatl_202412.cpg, Es_Lic_SCI_Zepa_SPA_Medalpatl_202412.dbf, Es_Lic_SCI_Zepa_SPA_Medalpatl_202412.prj, Es_Lic_SCI_Zepa_SPA_Medalpatl_202412.sbn, Es_Lic_SCI_Zepa_SPA_Medalpatl_202412.sbx, Es_Lic_SCI_Zepa_SPA_Medalpatl_202412.shp, Es_Lic_SCI_Zepa_SPA_Medalpatl_202412.shp.xml,

Es_Lic_SCI_Zepa_SPA_Medalpatl_202412.shx, Livestocktrails.cpg, Livestocktrails.dbf, Livestocktrails.prj, Livestocktrails.sbn, Livestocktrails.sbx, Livestocktrails.shp, ,Livestocktrails.shx, Livestocktrails.xml, MFE-Huercal-Overa_scrubland.cpg, MFE-Huercal-Overa_scrubland.dbf, MFE-Huercal-Overa_scrubland.prj, MFE-Huercal-Overa_scrubland.qmd, MFE-Huercal-Overa_scrubland.shp, MFE-Huercal-Overa_scrubland.shx, MFE-Huercal-Overa.cpg, MFE-Huercal-Overa.dbf, MFE-Huercal-Overa.prj, MFE-Huercal-Overa.shp, MFE-Huercal-Overa.shx, series of potential vegetation.cpg, series of potential vegetation.dbf, series of potential vegetation.prj, series of potential vegetation.shp, series of potential vegetation.shx

   d. **SIGPAC-Crops:** 04001_rec_2025_20250110.gpkg, Arable land_sigpac.cpg, Arable land_sigpac.dbf, Arable land_sigpac.prj, Arable land_sigpac.qmd, Arable land_sigpac.shp, Arable land_sigpac.shx, Citrus fruits_sigpac.cpg, Citrus fruits_sigpac.dbf, Citrus fruits_sigpac.prj, Citrus fruits_sigpac.qmd, Citrus fruits_sigpac.shp, Citrus fruits_sigpac.shx, cod_uso.qmd, cod_uso.xlsx, Fruits trees_sigpac.cpg, Fruits trees_sigpac.dbf, Fruits trees_sigpac.prj, Fruits trees_sigpac.qmd, Fruits trees_sigpac.shp, Fruits trees_sigpac.shx, Greenhouse_sigpac.cpg, Greenhouse_sigpac.dbf, Greenhouse_sigpac.prj, Greenhouse_sigpac.qmd, Greenhouse_sigpac.shp, Greenhouse_sigpac.shx, herbaceous crops.cpg, herbaceous crops.dbf, herbaceous crops.prj, herbaceous crops.qmd, herbaceous crops.shp, herbaceous crops.shx, Olive trees_sigpac.cpg, Olive trees_sigpac.dbf, Olive trees_sigpac.prj, Olive trees_sigpac.qmd, Olive trees_sigpac.shp, Olive trees_sigpac.shx, Unproductive_sigpac.cpg, Unproductive_sigpac.dbf, Unproductive_sigpac.prj, Unproductive_sigpac.qmd, Unproductive_sigpac.shp, Unproductive_sigpac.shx, Vineyards_sigpac.cpg, Vineyards_sigpac.dbf, Vineyards_sigpac.prj, Vineyards_sigpac.qmd, Vineyards_sigpac.shp, Vineyards_sigpac.shx
   e. **SIOSE -** Land uses and urban: areas of sparse vegetation.cpg, areas of sparse vegetation.dbf, areas of sparse vegetation.prj, areas of sparse vegetation.shp, areas of sparse vegetation.shx, artificial_siose.cpg, artificial_siose.dbf, artificial_siose.prj, artificial_siose.shp, artificial_siose.shx, crops_siose.cpg, crops_siose.dbf, crops_siose.prj, crops_siose.shp, crops_siose.shx, forest_siose.cpg, forest_siose.dbf, forest_siose.prj, forest_siose.shp, forest_siose.shx, road network_siose.cpg, road network_siose.dbf, road network_siose.prj, road network_siose.shp, road network_siose.shx, scrubland_siose.cpg, scrubland_siose.dbf, scrubland_siose.prj, scrubland_siose.shp, scrubland_siose.shx, water_siose.cpg, water_siose.dbf, water_siose.prj, water_siose.shp, water_siose.shx

- Hazard Assessment Euroheat Directory:
   a. heatwave_days_lat37.65_lon-2.02.csv
- Hazard Assessment Xclim local and HI:
   a. heatwave_days_local_definition_lat37.65_lon-2.02.csv,
   b. heatwave_duration_lat37.65_lon-2.02.csv
   c. heatwave_freq_lat37.65_lon-2.02.csv
   d. heatwave_index_lat37.65_lon-2.02.csv
   e. rothfusz_index_lat37.65_lon-2.02.csv
- Risk assessment LandSat Directory
   a. censal_ho_total.gpkg
   b. censal_ho_vulnerable.gpkg
   c. critical_infrastructure.gpkg
   d. ine_population.gpkg
   e. ine_vulnerable_density_area_by_category.csv
   f. ine_vulnerable_share.gpkg
   g. overheated_class_10.tif
   h. overheating_category_shares_and_areas.csv

i. risk_class_5_ine.tif
j. risk_class_5_worldpop.tif
k. worldpop_vulnerable_density_area_by_category.csv
l. worldpop_vulnerable_density_class_10.tif

- Risk projections Directory
  m. percent_relative_changes (directory): hwd_relative_change_rcp45_2016_2045.gpkg, hwd_relative_change_rcp45_2046_2075.gpkg, hwd_relative_change_rcp85_2016_2045.gpkg, hwd_relative_change_rcp85_2046_2075.gpkg
  n. reclassified_relative_changes (directory): hwd_relative_change_reclass_rcp45_2016_2045.gpkg, hwd_relative_change_reclass_rcp45_2046_2075.gpkg, hwd_relative_change_reclass_rcp85_2016_2045.gpkg, hwd_relative_change_reclass_rcp85_2046_2075.gpkg
  o. risk_census (directory): census_risk_full_rcp45_2016_2045.gpkg, census_risk_full_rcp45_2046_2075.gpkg, census_risk_full_rcp85_2016_2045.gpkg, census_risk_full_rcp85_2016_2045.gpkg
  p. risk_worldpop (directory). worldpop_risk_full_rcp45_2016_2045.gpkg, worldpop_risk_full_rcp45_2046_2075.gpkg, worldpop_risk_full_rcp85_2016_2045.gpkg, worldpop_risk_full_rcp85_2046_2075.gpkg
  q. censal_ho_total.gpkg
  r. censal_ho_vulnerable.gpkg
- aoi_munic.gpkg
- aoi_urban.gpkg

6 References

AEMET. (2023). Climate data and projections for Spain. Agencia Estatal de Meteorología. Retrieved from https://www.aemet.es

AdapteCCa. (2023). National Climate Change Adaptation Platform. Ministerio para la Transición Ecológica y el Reto Demográfico. Retrieved from https://adaptecca.es

Copernicus Climate Change Service. (2023). European Climate Atlas. European Centre for Medium-Range Weather Forecasts (ECMWF). Retrieved from https://atlas.climate.copernicus.eu

CSIC – Estación Experimental de Zonas Áridas. (2023). Desertification and land degradation studies in Almería. Consejo Superior de Investigaciones Científicas. Retrieved from https://www.eeza.csic.es

European Climate Assessment & Dataset (EURO-CORDEX). (2020). Regional climate downscaling projections for Europe. Coordinated Regional Climate Downscaling Experiment. Retrieved from https://cordex.org

Instituto Nacional de Estadística (INE). (2024). Demographic and socioeconomic indicators. Madrid: INE. Retrieved from https://www.ine.es

IPCC. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/9781009157896

Instituto de Salud Carlos III. (2024). Daily Mortality Monitoring System (MoMo). Madrid: Ministry of Health. Retrieved from https://momo.isciii.es

Junta de Andalucía. (2021). Andalusian Climate Action Plan (PAAC). Consejería de Agricultura, Ganadería, Pesca y Desarrollo Sostenible. Retrieved from https://www.juntadeandalucia.es

Ministerio para la Transición Ecológica y el Reto Demográfico. (2021). Spanish National Climate Change Adaptation Plan (PNACC 2021–2030). Madrid: MITECO. Retrieved from https://www.miteco.gob.es

Municipality of Huércal-Overa. (2022). Huércal-Overa 2030 Urban Agenda: Local strategy for sustainable development and climate adaptation. Ayuntamiento de Huércal-Overa. Retrieved from https://huercalovera2030.es/

Municipality of Huércal-Overa. (2020). General Urban Development Plan (PGOU). Huércal-Overa: Ayuntamiento de Huércal-Overa.

WorldPop. (2023). Global high-resolution population datasets. University of Southampton. Retrieved from https://www.worldpop.org