Deliverable Phase 1 – Climate risk assessment

Climate Risk Assessment in the Socially Vulnerable Communities of Aigaleo (Clisthenes)

Greece, Aigaleo

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Table of contents

Document Information....2
Table of contents....3
List of figures....5
List of tables....5
Abbreviations and acronyms....5
Executive summary....8
1. Introduction....9
1.1. Background....9
1.2. Main objectives of the project....9
1.3. Project team....10
1.4. Outline of the document's structure....11
2. Climate risk assessment – phase 1....13
2.1. Scoping....13
2.1.1. Objectives....13
2.1.2. Context....15
2.1.3. Participation and risk ownership....16
2.2. Risk Exploration....18
2.2.1. Screen risks (selection of main hazards)....18
2.2.2. Workflow selection....19
2.2.2.1. Urban Heatwaves....19
2.2.2.2. Wildfire....20
2.2.3. Choose Scenario....21
2.3. Risk Analysis....21
2.3.1. Urban Heatwaves....21
Hazard assessment....22
Risk assessment....22
2.3.2. Wildfire....23
Hazard assessment....24
Risk assessment....24
2.4. Preliminary Key Risk Assessment Findings....25
2.4.1. Severity....25
2.4.1.1 Urban Heatwaves....25
2.4.2. Urgency....39

2.4.3. Capacity 40
2.5. Preliminary Monitoring and Evaluation 41
3. Conclusions Phase 1- Climate risk assessment 42
4. Progress evaluation and contribution to future phases 43
5. References 44

List of tables

Table 1. CLISTHENES KPI and progress at M6 13
Table 2. Data overview for Urban Heatwaves workflow 22
Table 3. Data overview for Wildfire workflow 24
Table 4. Overview milestones 43

List of figures

Figure 1. Urban Heatwaves workflow. 20
Figure 2. Wildfire (FWI) workflow. 21
Figure 3. Risk matrix for the estimation of the heatwave risk severity 23
Figure 4. Heatwave occurrence per year under RCP4.5 (blue lines) and RCP8.5 (red lines) using health-related EU-wide definition of a heatwave for Aigaleo (37.99°N, 23.68°E). 25
Figure 5. Heat exposure based on LST (a), distribution of vulnerable population (b) and possible heat risk (c) in Aigaleo. 27
Figure 6. Relative change of heatwave occurrence based on RCP4.5 (left) and RCP8.5 (right) for the period 2016-2045 in reference to the period 1986-2015. Results are given for West Attica. 29
Figure 7. Scaled relative change of heatwave occurrence, based on RCP4.5 (left) and RCP8.5 (right) for the period 2016-2045 in reference to the period 1986-2015. Results are given for West Attica. 30
Figure 8. Scaled (from 1 to 10) vulnerable population density in West Attica. 31
Figure 9. Scaled relative change of heatwave risk to vulnerable population, based on RCP4.5 (left) and RCP8.5 (right) for the period 2016-2045 in reference to the period 1986-2015. Results are given for West Attica. 32
Figure 10. Geographical distributions of (a) the mean FWI of the period 2045-2054 and (b-k) the seasonal FWI of each year of the period 2045-2054, based on RCP4.5. The blue frame includes Dytikos Tomeas Athinon, where Aigaleo is located. 35
Figure 11. Geographical distributions of the fire weather season length (number of days with FWI>30) for the historical period 1985-2005 (left column) and the future period 2045-2054 (right column) for the greater area of Attica. The best (first row), worst (second row) and mean (third row) case conditions are presented. The blue frame includes the west part of Attica, where Aigaleo is located. 36
Figure 12. Geographical distribution of Fire Danger Index for the period 2045-2054, based on RCP4.5 over the greater area of Attica. The blue frame includes Dytikos Tomeas Athinon, where Aigaleo is located. 37
Figure 13. Geographical distribution of (a) burnable vegetation (%), (b) people living in Wildland Urban Interface (%), (c) protected areas fraction (%), (d) irreplaceability index, (e) population density (people/km^2) and (e) restoration cost index for the period 2045-2054, based on RCP4.5 over the greater area of Attica. The blue frame includes Dytikos Tomeas Athinon, where Aigaleo is located. 38

Figure 14. Geographical distribution of seasonal FWI (colors) and Fire Risk (red and green dots) for the period 2045-2054, based on RCP4.5 over the greater area of Attica. The blue frame includes Dytikos Tomeas Athinon,, where Aigaleo is located. 39

Abbreviations and acronyms

Abbreviation / acronym	Description
AGL	Municipality of Aigaleo
NCSRD	National Centre of Scientific Research “Demokritos”
CRA	Climate Risk Assessment
ELSTAT	Hellenic Statistical Authority
PESPKA	Regional Adaptation Plan of Attica
SECAP	Sustainability Energy Climate Action Plan

Executive summary

This deliverable presents the initial Climate Risk Assessment (CRA) for the Municipality of Aigaleo (AGL), developed within the framework of the CLIMAAX – Clisthenes project. It focuses on the identification of key climate hazards, vulnerabilities, and capacities, aiming to support the future development of an inclusive and locally adapted climate adaptation strategy.

The main hazards addressed are urban heatwaves and wildfires, both of which are becoming increasingly frequent and severe in the region. Vulnerability hotspots include areas such as Eleonas, neighborhoods adjacent to Aigaleo Grove, and dense residential zones near the Kifissos Avenue.

The analysis combines available datasets (e.g. GIS data, TransformAr climate stations), stakeholder input, and selected CLIMAAX workflows (EuroHEAT and FWI). Initial steps included internal training of 20 staff members and preliminary identification of vulnerable groups and areas. However, data delays, especially socio-economic data from ELSTAT, limit the resolution of current analysis.

The CRA process will be expanded through participatory workshops, aiming to validate early findings and explore key issues such as energy poverty, local perceptions of acceptable risk, and the adaptive capacity of public services and infrastructure.

The work undertaken in this deliverable lays the groundwork for the refinement of AGL's SECAP, the design of a dedicated adaptation strategy, and the implementation of practical, community-driven resilience measures and interventions in the next phases of the project.

This initial CRA highlights the climate challenges facing Aigaleo and provides a structured foundation for inclusive, evidence-based planning. The process will be further enriched through community engagement and cross-sectoral cooperation in the coming phases of the Clisthenes project.

1. Introduction

1.1.Background

Municipality of Aigaleo, is situated in the western sector of Athens metropolitan area, is a densely populated urban zone covering approximately 6.5 km² with around 70,000 residents. Aigaleo, historically, was established in the aftermath of the 1922 population exchange to accommodate refugees from Minor Asia, Pontus, and Assyrian communities. This foundational moment shaped its strong working-class identity, collective memory, and tradition of solidarity, which continue to define the municipality's social and cultural fabric.

Over the years, Aigaleo has evolved into a strategic commercial and residential hub due to its central location and proximity to major road arteries such as Iera Odos, Thivon Avenue and Kifissos Avenue. Part of the Eleonas area—an industrial zone, not yet urbanized, currently in transformation—falls within its boundaries with Athens, enhancing its economic role but also posing urban and environmental challenges. Despite being highly urbanized and compact, Aigaleo maintains an important green asset, most notably the Aigaleo Grove "Baroutadiko", the largest green space in Western Athens and a key environmental and recreational resource. Mount Aigaleo further defines the western edge of the city, providing ecological and symbolic significance.

Aigaleo's population today reflects multiple layers of vulnerability. In addition to its aging population and long-standing lower-income households, the municipality is home to migrants and refugees from more recent migration waves, contributing to its multicultural character but also increasing social demands. The cumulative impact of the economic crisis, the COVID-19 pandemic, and intensifying climate-related risks has weakened previously strong community ties and placed pressure on local social services.

Aigaleo experiences typical Mediterranean urban environment (Csa classification according to Koppen climate zones). However, the effects of climate crisis are increasingly evident. Extreme temperatures (both winter and summer), prolonged and frequent heatwaves, and the intensification of the urban heat island effect due to dense building stock and limited vegetation have altered living conditions and public health dynamics. The area also faces air quality degradation and growing exposure to extreme weather events, including wildfires in nearby zones. These environmental stressors disproportionately affect vulnerable populations and demand urgent adaptation measures.

1.2.Main objectives of the project

The CLIMAAX project offers a critical opportunity for AGL to strengthen its climate resilience through a structured, inclusive, and data-informed approach. As an urban area facing increasing environmental pressures, social vulnerabilities, and dense urbanization, AGL seeks to turn these challenges into drivers for equitable and sustainable transformation.

The municipality's participation in CLIMAAX focuses on four key objectives:
– The development of a **concrete, holistic, and realistic Climate Vulnerability Assessment**, tailored to local environmental and social conditions,
– The **localization of CLIMAAX tools and methodologies** to refine the existing SECAP and formulate

a climate adaptation strategy aligned with municipal priorities,
– The **identification of inclusive and just adaptation measures**, with a focus on engaging citizens and particularly vulnerable groups such as migrants, elderly residents, and low-income households,
– The **utilization of climate data** collected from monitoring stations installed under the TransformAr project to inform planning with real-time, location-specific evidence.

The CLIMAAX Handbook will directly support the municipality in achieving several strategic outcomes:

1. **Climate-proofing of Critical Services**
   The Handbook will guide the municipality in identifying actionable and cost-effective measures to safeguard vital infrastructure from climate extremes, while also contributing to the **reduction of energy consumption**, particularly in public buildings and services.
2. **Promoting a Just and Inclusive Transition**
   By identifying gaps in service provision and understanding the needs of vulnerable populations, the CLIMAAX process will help ensure that adaptation planning is socially grounded and equitable.
3. **Fostering Climate Awareness and Citizen Engagement**
   CLIMAAX offers the opportunity to **upgrade and institutionalize the TransformAr citizen awareness app** as an official municipal tool, helping to raise public awareness and promote participatory climate action.
4. **Shaping Positive Perceptions of European Projects**
   The dissemination of project results and good practices will support broader community understanding of the **positive role of EU initiatives** in shaping local sustainability and resilience.
5. **Strengthening the SECAP Framework**
   The integration of CLIMAAX tools will enable the municipality to **enhance key SECAP pillars**, embedding inclusion, justice, and long-term sustainability into its climate resilience strategy.

In summary, CLIMAAX provides AGL with the necessary tools and methodology to advance a forward-looking urban transformation—one that is rooted in data, aligned with European climate adaptation priorities and shaped by local community participation input.

1.3.Project team

The project team is composed of experienced professionals from the Department of Development and Planning of AGL and the research team of NCSRD.

The Department of Development and Planning is responsible for the application and implementation of all national and European projects in AGL. The team consists of Dr. Dimitris Tzempelikos, the Head of the Dept. and Evangelia Bakogianni project manager and social scientist in European projects.

Dr Dimitris Tzempelikos is a mechanical engineer experienced in the fields of energy, renewable energy technologies, modern financing mechanisms and elaboration of sustainable energy and climate action plans. He participates and coordinates AGL team in several European projects.

Evangelia Bakogianni is an architect engineer (MArch) and social scientist working on the fields of urban planning, community engagement and participatory action research. She is participating in technical, social and environmental EU projects.

NCSRD is the largest multidisciplinary research center in Greece and participates in the project as Aigaleo subcontractor. The scientific group EREL[1] , which participates in the project, takes a comprehensive R&D approach to sustainable development and climate resilience, integrating a range of topics and modelling methodologies. The team consists of Dr. Thanasis Sfetsos and Dr. Maria Gavrouzou assistant researcher in NCSRD.

Dr. Athanasios Sfetsos, received a B.Sc. in Physics from University of Patras in 1995 and a Ph.D. in Electrical Engineering from Imperial College, University of London (1999). Research Director at the Institute of Nuclear and Radiological Sciences, Technology Energy and Safety at NCSR Demokritos in the field of "Climate Change and Critical Infrastructure Protection" since 2021. His research interests fall to the thematic priorities of (i) Critical Infrastructure Protection (risk analysis of interconnected heterogeneous systems), (ii) Resilience and Crisis Management with emphasis on natural hazards; and (iii) Climate Change analysis and provision of climate services. Responsible for the establishment and maintenance of the EREL High Performance Cluster, which is the largest computational facility by a similar magnitude laboratory.

Dr. Maria Gavrouzou is a physicist with a MSc degree in Atmospheric Sciences and Environment and a Doctorate degree in Atmospheric Physics from University of Ioannina, Physics Department. She has knowledge of several programming languages, namely C++, IDL, Fortran and Python and experience in climate data analysis and climate modeling. Moreover, she has been involved in European Projects which aim to the climate resilience and adaptation.

1.4.Outline of the document's structure

This document is structured as follows:

- **Part 1. Introduction**
  Provides background on the local context of AGL and the characteristics of the area, the rationale for conducting a climate risk assessment regarding the CLIMAAX – Clisthenes project.
- **Part 2. Climate Risk Assessment (CRA)**
  Structured according to the CLIMAAX Handbook, this section covers:
  - Scoping of objectives, limitations, and stakeholders involved;
  - Analysis of the local context, including governance, policies, and environmental challenges;
  - Stakeholder engagement and risk ownership processes;
  - Selection of key hazards (heatwaves and wildfires) and assessment of available data;
  - Capacity mapping across social, institutional, and technical dimensions.
- **Part 3: Methodologies and Next Steps**
  Describes the analytical frameworks and CLIMAAX workflows applied in this phase

[1] https://climaerel.ipta.demokritos.gr/

(EuroHEAT, Fire Weather Index), as well as the participatory methodologies planned for the next phase, including local workshops and vulnerability co-identification.

- **Part 4: Conclusions**
  Summarizes the key findings of the first CRA phase and outlines how the results will inform the development of the climate adaptation strategy and the refinement of the municipality's SECAP.

Annexes include data tables, references to external documents, and supporting visual material.

2. Climate risk assessment – phase 1

2.1.Scoping

2.1.1. Objectives

The Climate Risk Assessment (CRA) for AGL aims to deliver a concrete, holistic, and realistic understanding of local climate vulnerabilities that affect both infrastructure and social structure. The purpose of this process is to support the municipality in identifying risks, setting priorities, and co-developing just and inclusive adaptation measures and strategies that align with long-term sustainability goals.

The expected outcomes, as we mentioned above, include:

– The refinement of the existing SECAP[2] through the localization of CLIMAAX tools and methodologies
– The design of a dedicated operational plan linked to a climate adaptation strategy[3]
– The use of localized climate data (e.g., from the TransformAr climate stations) to inform risk assessment and planning
– The development of actionable, socially equitable, and technically feasible climate resilience policies and measures.

This CRA will serve as a practical decision-support tool for municipal entities, feeding directly into environmental urban policy, infrastructure planning, and the design of targeted social measures and services.

Within the proposal AGL has proposed the following set of indicators (KPI) to monitor the progress of the CLISTHENES project. The progress of the attainment is depicted in the Table 1 below

Table 1. CLISTHENES KPI and progress at M6

KPI number	Description	Progress at M6
KPI1 (@M3)	20 staff members of EGL and NCSRD trained in the CLIMAAX approach	done
KPI2 (@M7)	5 new climate indicators related to vulnerable communities identified	Designed

[2] https://ep.egaleo.gr/sites/default/files/2024-09/SDAEK-Aigaleo_2021.pdf
[3] https://www.aigaleo.gr/epixirisiako-sxedio/

KPI3 (@M15)	3 impact chains identified and validated	Not started
KPI4 (@M7, M15)	2 on-site meetings	1 performed at M6
KPI5 (@M15)	8 validation events conducted with local representatives	Not started
KPI6 (@M22)	1 scientific publication produced	Not started
KPI7 (@M22)	20 posts made on EGL's and NCSRD's social media	1 made
KPI8 (@M16)	1 scalable policy canvas produced	Not started
KPI9 (@M22)	5 meetings conducted with local stakeholders for replication and upscaling	Not started
KPI10 (@M6)	2 workflows successfully applied on D1	Done
KPI10 (@M15)	2 workflows successfully applied on D2	Not started

However, collecting and processing data across all these domains presents significant challenges. Several **data gaps and limitations** have already been identified—most notably in accessing detailed, up-to-date socio-economic data at neighbourhood level or even more closely to building block level. Requests to the Hellenic Statistical Authority (ELSTAT) for specific datasets have faced delays, affecting the depth and accuracy of the analysis.

Moreover, the level of spatial detail required to capture urban inequalities as accurately as possible is not always available in open data sources. While in several places the barrier of protecting sensitive personal data is also encountered, even in data requested by the municipality itself.

Despite these constraints, the CRA will proceed using a hybrid approach, combining available quantitative data with qualitative inputs, participatory insights, and local knowledge. The geographic focus will be the entire AGL, with emphasis on areas of high density, limited green areas, and social vulnerability. The analysis will be scaled up as new data is added.

2.1.2. Context

In recent years, AGL has been increasingly affected by the consequences of climate crisis and other natural hazards. Key climate-related threats include extreme heatwaves and the rising risk of wildfires, while urban flooding, air pollution, and the area's vulnerability to seismic activity also represent significant challenges for urban resilience. These risks are recognized in the city's strategic planning documents and reflect both its geographic position and dense urban character (Municipality of Aigaleo Strategic Plan 2024–2028, Section 1.2.1.1).

The urban structure of Aigaleo, with limited vegetation and high building density, intensifies the urban heat island effect, exacerbating heat-related health and infrastructure stress. The municipality also borders peri-urban green areas and contains important urban green lungs, such as Mount Aigaleo and Aigaleo Grove "Baroutadiko", the largest park in Western Athens. These green areas are increasingly at risk from wildfires, especially during extended heatwaves and dry spells (Municipality of Aigaleo Strategic Plan 2024–2028, Section 1.2.4).

To date, these climate and natural hazards have been addressed in a fragmented and sector-specific manner, primarily through emergency management protocols, basic mitigation actions, and limited environmental planning. There is no unified Climate Risk Assessment (CRA) in place that systematically integrates climate projections, social vulnerability data, and critical infrastructure exposure.

The CLISTHENES project aims to address this gap by introducing a structured, inclusive, and locally adapted CRA process. This effort aligns with the National Adaptation Strategy (NAS), the Regional Adaptation Plan of Attica (PESPKA), and broader frameworks such as the European Green Deal and Mission on Adaptation to Climate Change.

The governance context in AGL includes its SECAP (developed under the Covenant of Mayors), national civil protection and planning legislation, and strategic commitments to green transition and urban sustainability as outlined in the municipal Strategic Plan. These efforts are supported by participation in multiple European projects such as *TransformAr*, *Rock the Block*, *BIN2BEAN*, *C2IMPRESS* and the most recent ones *Med-IREN* and *ClimateAdapt4EOSC*, which contribute technical tools, awareness mechanisms, and green infrastructure pilots (Municipality of Aigaleo Strategic Plan 2024–2028, Section 3.4).

Several sectors in Aigaleo are particularly sensitive to climate impacts:

- **Public health**, especially for vulnerable groups such as the elderly, low-income residents, and people with disabilities, migrant populations and homeless people
- **Built infrastructure**, including energy-inefficient buildings, stormwater networks, and transport systems vulnerable to flooding and heat stress, as well as the infrastructure that has been put in place to enclose the streams that run through the area
- **Energy**, where building retrofits and renewable energy deployment are critical goals;
- **Social protection and civil society**, which play a key role in responding to and mitigating the impacts of environmental stress on the most vulnerable and on social cohesion (Municipality of Aigaleo Strategic Plan 2024–2028, Sections 1.3.6 & 1.4.2), as another

factor emerging from the climate crisis is the production of psychological problems such as stress, frustration and disengagement from society.

The local climate challenge is also shaped by broader external factors, including rising energy costs, geopolitical instability (affecting refugee and migration flows), and the strategic shift in EU policy towards sustainability and resilience.

Adaptation interventions include:

- **Nature-based solutions**, such as green corridors, urban reforestation, and bioclimatic upgrades to public spaces (through Med-IREN project)
- **Climate monitoring infrastructure**, using tools and data generated through the TransformAr project
- **Community-centered planning**, ensuring the meaningful engagement of citizens, civil society along with the municipal and regional bodies
- **Integration of climate resilience in urban governance**, through evidence-based, equity-focused approaches.

By focusing primarily on heatwaves and wildfires, while also acknowledging the threats of flooding, pollution, and seismic risk, CLIMAAX offers AGLthe opportunity to move toward a climate-resilient, inclusive, and proactive urban future.

2.1.3. Participation and risk ownership

Stakeholder engagement has been a key priority from the early stages of the CLIMAAX project in Aigaleo. On 25 February 2025, the Municipality organized an initial training session for municipal staff and researchers from NCSRD, introducing them to the CLIMAAX methodology. This session brought together representatives from the Municipal Technical Services, Social Services, Civil Protection, the Education Directorate, local schoolteachers and volunteers from the emergency aid organization EPOMEA. It marked the starting point of a broader strategy to build internal capacity and foster cross-departmental collaboration on climate risk issues.

Building on this first step, the municipality is now preparing a series of participatory workshops involving a broader spectrum of local stakeholders. These events are designed to promote dialogue, identify vulnerabilities, and co-design practical adaptation measures. In this context, stakeholder engagement is not treated as a one-off consultation but as a dynamic and evolving process.

A diverse range of actors have been identified as relevant to the project, each bringing a different perspective, expertise, or reach. Public sector stakeholders include municipal services (Police, Civil Protection, Technical Services, Social Services, Cleanliness and Recycling, and Transport), the Region of Attica, the West Athens Functional Urban Area (FUA), and neighboring municipalities. Scientific and technical institutions such as NCSRD, the West Attica and Panteion Universities, and schools across all education levels provide data, tools, and knowledge. Non-governmental stakeholders—ranging from local parent associations and NGOs active in disaster management to historic and cultural organisations—are critical to embedding the project in the community. Finally, private sector actors (chambers of commerce, SMEs, energy professionals, and the local media) and European entities (e.g. DRMKC, EU Risk Data Hub) contribute to outreach, data sharing, and policy learning.

Particular attention is being paid to identifying and supporting vulnerable groups and areas. Based on the outcomes of previous projects participatory design workshops such as *C2IMPRESS*, the community has recognized a number of population groups at risk: homeless individuals, people with disabilities, elderly residents, children, low-income households, and those living in structurally inadequate housing. Spatially, the areas identified as most vulnerable include Eleonas area, neighborhoods adjacent to Aigaleo Grove and the Kifissos avenue, historic refugee settlements, and Social Housing Complex in Thessalonikis road. These early findings will be further explored and validated in the participatory workshops planned for the next phases of the project.

In addition, the municipality plans to open a structured discussion with local stakeholders on energy poverty—a growing form of vulnerability with significant implications for heat resilience and adaptive capacity. Citizens will be invited to reflect on whether they consider themselves energy-vulnerable and to help identify the real conditions that contribute to this new reality. The aim is to co-design realistic and implementable responses that align with the institutional constraints of Greek local governance.

In terms of risk governance, the Municipal Department of Civil Protection is the key authority responsible for strategic planning and emergency preparedness. It coordinates with the Municipal Police, Social Services, and Technical Works to implement risk management activities and crisis response plans. This structure reflects the current legal and administrative framework in Greece, where local governments operate within clearly defined but limited autonomy.

As highlighted in previous participatory processes, such as *C2IMPRESS*, local perceptions of acceptable risk are not only linked to the severity or probability of an event but also to the readiness of the system to respond. Participants have emphasized that the state of public and private infrastructure, the reliability of early warning systems, and the level of community education all play a critical role in determining what is perceived as a tolerable level of risk.

The municipality has adopted a multi-level and inclusive communication strategy to share the results of the climate risk assessment. These include:
– Public events and workshops with local stakeholders,
– Educational programs in schools to foster awareness among children, seen also as indirect influencers of adult behavior,
– Use and further development of the citizen awareness app created under the TransformAr project, evolving it into an engagement tool for AGL,
– Regular updates on social media channels managed by both the AGL and NCSRD.

These outreach efforts are embedded in the project's broader KPIs, which include training 20 staff members, identifying five new climate vulnerability indicators (including climate anxiety and energy poverty), organizing multiple stakeholder validation events, and producing a scalable policy canvas and scientific publication. The project also foresees a total of five meetings with external municipalities and institutions to promote replication and upscaling.

In summary, AGL is laying the groundwork for a locally grounded, participatory, and cross-sectoral approach to climate risk governance, where both institutional actors and citizens mutually collaborate in building resilience.

2.2. Risk Exploration

2.2.1. Screen risks (selection of main hazards)

AGL is exposed to a range of environmental hazards that are increasingly intensified by the effects of climate change and urban density. Based on preliminary assessments and stakeholder consultations, the two main climate-related hazards selected for in-depth analysis under the CLIMAAX risk assessment are:

- Urban Heatwaves, and
- Wildfires.

These risks were selected due to their growing intensity, increasing frequency, and direct impacts on the community and everyday life especially vulnerable population groups and essential infrastructure. In addition to these core hazards, the municipality also faces urban flooding, air pollution, and seismic vulnerability, which, although not covered in detail under the current CRA, provide an important contextual backdrop for future resilience planning (Municipality of Aigaleo Strategic Plan 2024–2028, Sections 1.2.1.1 & 1.2.4).

Urban heatwaves have become a dominant and recurring threat, with recent years showing a significant increase in frequency and duration. The densely built environment of Aigaleo, combined with limited green spaces, exacerbates the urban heat island effect, particularly in southeastern parts of the municipality, along major roads such as Kifissos Avenue, where surface temperatures are consistently elevated. Vulnerable populations — including the elderly, children, individuals with chronic illness, and low-income households — are disproportionately affected, especially those residing in poorly insulated or overcrowded buildings.

In parallel, the risk of wildfires is steadily increasing, particularly in and around the municipality's green spaces such as Mount Aigaleo, Elaionas unurbanized areas and the Aigaleo Grove, which are vital ecological and recreational areas for the community. Although the municipality is largely urban, the interface between built-up areas and vegetation, along with the effects of prolonged droughts and higher seasonal temperatures, create the conditions for potential wildfire outbreaks that could endanger both health and property.

Data supporting this hazard screening include findings from the TransformAr project's climate monitoring stations, vulnerability mappings from past EU projects (e.g. C2IMPRESS), and GIS layers maintained by the municipality's technical services. The CLIMAAX workflows selected — EuroHEAT for heatwaves and the Fire Weather Index (FWI) approach for wildfires — have provided preliminary insights into risk concentration, frequency projections (e.g. 90%–140% increase in heatwaves in West Attica), and vulnerability hotspots.

At the same time, important data gaps remain, particularly in the granularity of social vulnerability indicators. While some baseline information is available from municipal services and local GIS tools, access to detailed socio-economic data from ELSTAT has been facing some delays. In addition, current datasets (e.g. WorldPop) often fail to reflect actual urban population distributions due to generalized modeling methods. Further qualitative data from upcoming participatory workshops is also needed, especially on community perceptions of energy poverty and informal vulnerability conditions.

Despite these limitations, the project will proceed using a mixed-methods approach, integrating available geospatial, statistical, and participatory inputs. Emphasis will be placed on triangulating data across sources to validate findings and guide targeted adaptation measures. As new data becomes available — particularly from participatory workshops and stakeholder consultations — the risk screening will be revisited and refined to ensure an inclusive, evidence-based climate adaptation strategy for Aigaleo.

2.2.2. Workflow selection

Based on what was discussed in the previous section (Section 2.2.1) the main hazards of interest for Aigaleo city are the Urban Heatwaves and Wildfires. Thus, the corresponding CLIMAAX workflows were selected and run. More details about the choices made for the running of each workflow are given in the following sub-sections (sub-sections 2.2.2.1 and 2.2.2.2). All worksflows within CLISTHENES considered the following **social, economic, health, and infrastructure vulnerability indicators**:

– Demographics (age, sex);
– Socioeconomic status (education, income, inequality, poverty);
– Indicators of spatial deprivation (e.g. Social Vulnerability Index);
– Building characteristics (e.g. material, use, age);
– Infrastructure and road network exposure (e.g. proximity to wildland-urban interfaces via OSM data).

2.2.2.1. Urban Heatwaves

For the Urban Heatwaves there is only one workflow in CLIMAAX handbook, which is the one that also ran for the case of Aigaleo city. Thus, in this section some details about the choices made within the workflow will be given.

The heatwave workflow methodology provided by CLIMAAX is designed to help in exploring local and regional risks presented by heatwaves and assessing the impact of climate change on the heatwave hazard. This is conducted in three steps which include: (i) the understanding of the trends in the occurrence of hot days/nights under climate change (hazard assessment), (ii) the identification of the overheated areas in the urban environment (for both historical and future periods) and (iii) the identification of vulnerable population groups (Figure 1).

On the first step, the hazard assessment can be assessed using two different methodologies, namely EuroHEAT and Xclim. The two methodologies differ in terms of heatwave definition. EuroHEAT defines the heatwave as “a period where the maximum apparent and the minimum temperature is over the 90th percentile of the monthly distribution for at least two days”. The monthly distribution is calculated from the daily temperatures over the 30-year period from 1971 to 2000. On the other hand, in Xclim approach, heatwaves are defined based on user-defined absolute temperature thresholds for the maximum and minimum daily temperatures (day and night temperatures) and a minimum duration. According to the handbook recommendations, EuroHEAT workflow is preferable because it is based on several regional climate models, in contrary to the Xcim which uses only one regional model. For this reason and also for time saving the EuroHEAT workflow was selected and run for Aigaleo city. The second step in Urban Heatwaves workflow includes the identification of the overheated areas in the built environment for the historical period (2013-2021) and the heatwave risk under the climate change (2016-2045). Last, the third step includes vulnerability estimation. In this workflow only the population vulnerability is assessed. Thus, as vulnerable groups to the heatwaves are considered children under 5 years old and males and females over 65 years old. More details for the selected workflows will be given in Section 2.3 of the current deliverable.

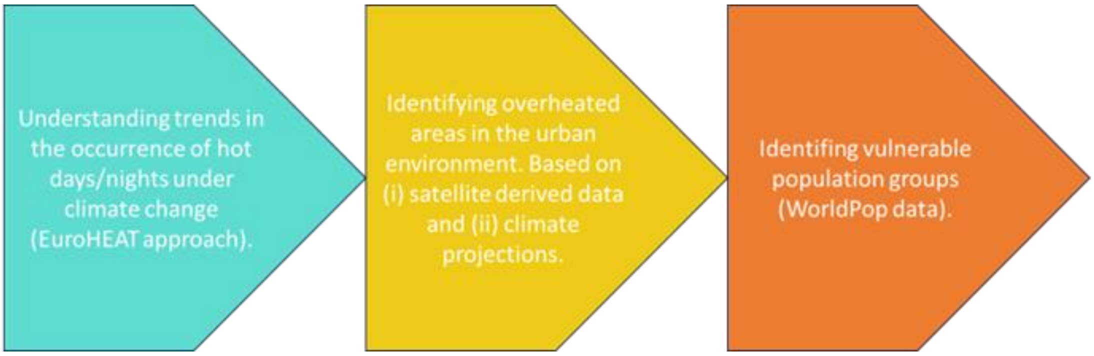


Figure 1. Urban Heatwaves workflow.

2.2.2.2. Wildfire

For the Wildfires, CLIMAAX provides two approaches/workflows. The first one, is called “Machine Learning-Based Hazard Mapping” and uses Machine Learning (ML) model to assess the wildfire susceptibility based on multiple climatic and geographic parameters. The model which is based on Random Forest Classifies (RF) and is trained using historical wildfire data and climate projections. This way, the model provides wildfire predictions on a high resolution. The training of this model requires the gathering of different kinds of data such as Digital Elevation Model (DEM) raster data, land cover data, dataset of historical fires, fuel availability and fire danger, vulnerability data, Exposure data. Thus, for time saving, at this first stage of the project, the second workflow named “Fire Weather Index” was selected and ran for Aigaleo city (Figure 2). In the workflow, the wildfire development risk is assessed based on Fire Weather Index (FWI) and a set of wildfire vulnerability indicators. Thus, on the first step, the workflow determines the areas with higher probability for wildfire development based on climatic conditions and fuel availability. On the second step, it identifies the most vulnerable areas from human, economic and environmental aspect. On the third step, the information produced in the first two steps, i.e., the exposure and the vulnerability to wildfires, is combined to estimate the wildfire risk. This is done using Pareto analysis, which gives the group of pixels that have the highest risk profile assuming that all factors considered in the analysis equally contribute to wildfire risk. More details about the workflow input data are given in Section 2.3 in the current deliverable.

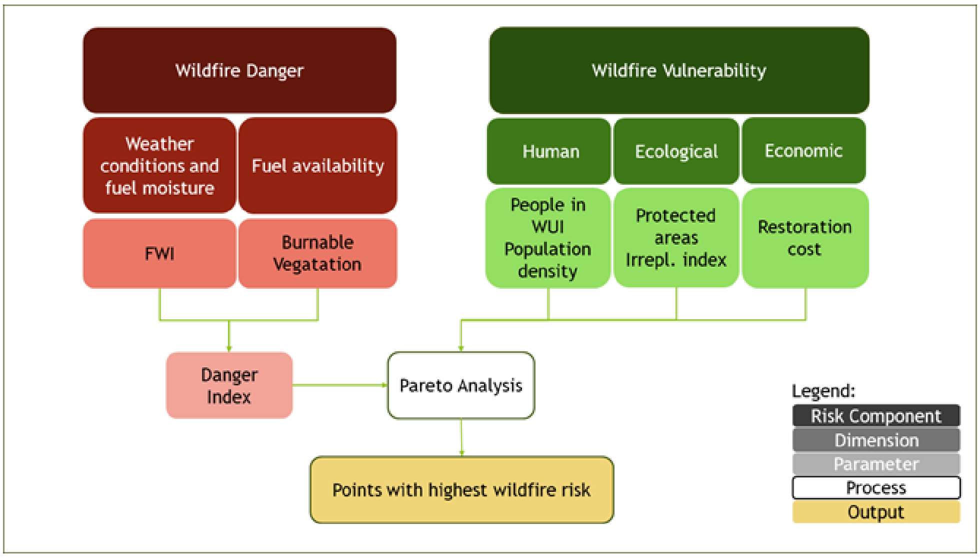


Figure 2. Wildfire (FWI) workflow.

2.2.3. Choose Scenario

Regarding the heatwaves, the available CLIMAAX workflow combines the hazard with the vulnerability for the risk estimation for the current and projected climate (RCPs 4.5 and 8.5) in the regional resolution for selected EU regions. Regarding the climate projections, the workflow provides information about the projected change in the heatwave occurrence for the near future 2016-2045 and further future 2046-2075. For the case of Aigaleo, only the near future projections are selected and ran. This is done in order to ensure consistent population data.

For the wildfires, the FWI hazard assessment explores FWI seasonal and daily data and provides information on the projected changes of the fire weather season length based on RCP 4.5 and for future periods. Given that the FWI is only composed of climatic variables, climate models can be used to simulate future changes in daily and seasonal FWI values to get an estimate of how the fire weather hazard might evolve with climate change. Seasonal FWI data comes in 5 years' timeframes. In Aigaleo case two of them, 2046-2050 and 2051-2055, were selected. For the emission scenario RCP4.5 was selected out of the 4 available in total, with historical, RCP2.6 and RCP8.5 being the other options. The multi-model ensemble means as the source of the projection as this provides the highest robustness of results was preferred. Finally, for the severity of the projections the ‘mean’ case scenarios, was selected for Aigaleo among ‘best’, ‘worst’ and ‘mean’ choices.

2.3.Risk Analysis

2.3.1. Urban Heatwaves

In Table 2-1 an overview of the hazard, vulnerability and exposure data used for the risk assessment of Aigaleo based on satellite derived data and climate projections. Moreover, in the last column of the table the kind of the produced risk output is given. For both approaches, the EuroHeat pre-computed heatwave days and the WorldPop were used for the hazard and vulnerability assessment respectively. Land Surface Temperature (LST) from Landsat8 were also used to assess the exposure in the satellite-derived data approach. More details about the datasets used are given in the following sub-sections.

Table 2. Data overview for Urban Heatwaves workflow

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
Heatwave days (EuroHeat)	Population Density (WorldPop)	Land Surface Temperature (Landsat8)	Possible heat risk level to vulnerable population
Heatwave days (EuroHeat)	Population Density (WorldPop)	-	Relative change of heatwave risk to vulnerable population groups

Hazard assessment

The heatwave hazard assessment applied on Aigaleo is directly based on an existing dataset of heatwave available on Climate Data Store (CDS). This dataset developed in the framework of the EuroHeat project, which defines the heatwaves based either on the Health-related EU-wide definition or on the National heat-wave definition. For the Aigaleo case, the former one was adopted, which defines the heatwaves for the summer period of June to August "as days in which the maximum apparent temperature (T_{appmax}) exceeds the threshold (90th percentile of T_{appmax} for each month) and the minimum temperature (T_{min}) exceeds its threshold (90th percentile of T_{min} for each month) for at least two days". This definition applies thresholds on both minimum and maximum temperatures and thus it accounts for the effect of minimum temperature on the severity of a heatwave. Another advantage of this approach is that the indicators are pre-computed and thus less data are needed to be downloaded and processed. The data are available on a 12×12km grid for the time period 1986-2085 for the whole EU.

Risk assessment

For the heatwave risk assessment of Aigaleo both satellite-derived data and projected changes workflows ran. The former one aims to identify the problematic (most overheated) areas and who or what is exposed. It uses the hazard assessment for understanding the trends in the occurence of hot days in the climate change scenarios and land surface temperature (from RSLab Landsat8, resolution: 30x30m) for the identification of urban heat islands (areas most exposed to heat). The distribution of vulnerable population, based on population distribution data from WorldPop are used to identify who is exposed. Then, the heatwave risk is calculated based on the 10+10 risk matrix (Figure 3).

Regarding the heatwave risk under climate change, it was estimated by combining the hazard Euroheat data with the vulnerability data from WorldPop. This combination gives a risk estimation for the current and projected climate (RCPs 4.5 and 8.5) in NUTS3 level. Specifically, the used workflow aims to identify regions within the study area that will be most affected by changes in heatwave occurrence and have the highest concentration of vulnerable population groups. The results provide insight into which areas may be more impacted by climate change. If some regions are identified as being at a 'Very High' risk level, it indicates that these regions could experience the greatest increase in heat-wave occurrences within the selected country.

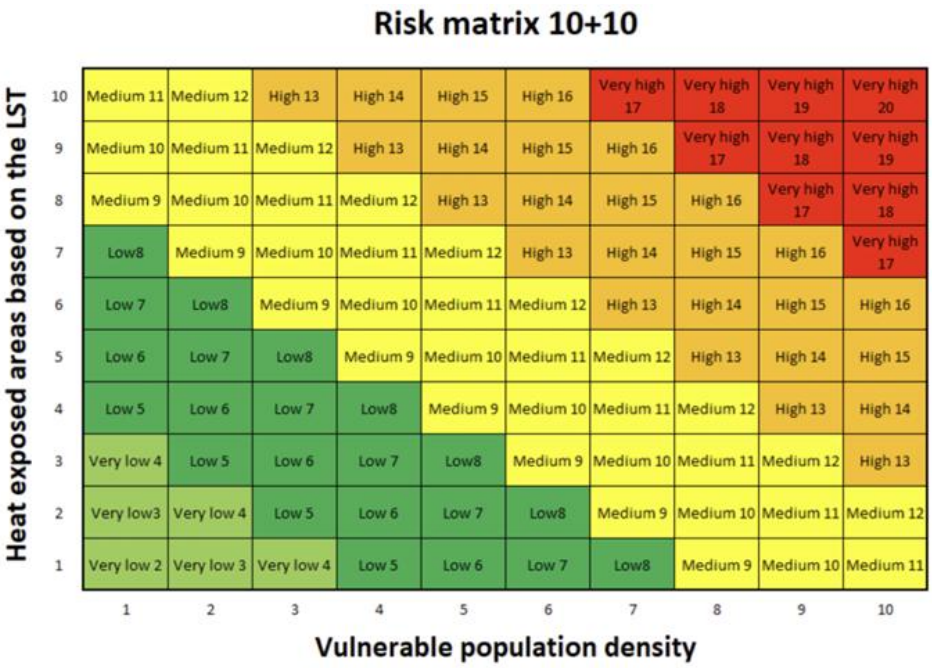


Figure 3. Risk matrix for the estimation of the heatwave risk severity

2.3.2. Wildfire

The FWI workflow which ran for Aigaleo, produces an assessment of wildfire development risk based on the seasonal FWI and a range of parameters linked to wildfire vulnerability. It consists of a simple tool to assess which areas of Aigaleo have the most favorable conditions for wildfire development based on climatic conditions and fuel availability. Moreover, it provides information on which areas are the most vulnerable to wildfire from a human, economic and environmental aspect. Synthetizing information about wildfire danger and vulnerability, the workflow finally produces an assessment of wildfire risk, pointing out which areas should be prioritized by adaptation measures.

In Table 2-2 the different kinds of data used in the workflow are presented. For the hazard assessment, seasonal and daily FWI data were used to estimate the changes in intensity of fires and the length of fire season respectively. These data are produced by global and regional climate models and sourced from the Copernicus Climate Data Store. The seasonal FWI represents the mean fire weather index value over the European fire season (June-September). This is calculated as the sum of the daily fire weather index over the European fire season divided by the total number of days within this date range. Seasonal FWI data comes in 5 years timeframes. For the Aigaleo case, two of them were selected (2046-2050 and 2051-2055). For the emission scenario the RCP4.5 was selected among the 4 available in total, with historical, RCP2.6 and RCP8.5 being the other options. Regarding the model, the multi-model ensemble mean was selected as this provides the highest robustness of results. Last, for the severity of the projections the 'mean' case scenarios were chosen. The abovementioned data are available on NUTS2 or NUTS3 level and at 0.11° x 0.11° spatial resolution. For the case of Aigaleo, data for West Attica downloaded. Fuel availability was estimated based on the percentage of burnable vegetation. This information is produced by EFFIS and covers the whole European domain. The extracted burnable area data reprojected and interpolated to match the coordinate system and resolution of the FWI dataset.

For the vulnerability estimation the following data produced by EFFIS downloaded and extracted:

- Population living in the Wildland Urban Interface, representing the share of total population living in the periurban areas bounding forested or vegetated areas
- Protected Areas distribution, representing the share of each pixel of the map covered by a protected natural area
- Ecosystem Irreplaceability Index, representing the uniqueness and inherent value of the ecosystems present in each pixel
- Population Density
- Ecosystem Restoration Cost Index, representing the relative restoration cost of land in case of loss by wildfire

The extraction and reprojection procedure were the same as for the burnable vegetation.

Table 3. Data overview for Wildfire workflow

Hazard data	Vulnerability data	Exposure data	Risk output
FWI (EURO-CORDEX)	Population living in the Wildland Urban Interface, Protected Areas, Ecosystem Irreplaceability Index, Population Density, Ecosystem Restoration Cost Index	Burnable Vegetation	Points with highest wildfire risk

Hazard assessment

The workflow for the hazard assessment run for Aigaleo, provides an overview of (i) spatial and temporal trends in FWI intensity and (ii) the changes in the fire weather season duration. Variations in seasonal FWI intensity determine how changing climate conditions are influencing the likelihood of wildfire development. An increase in seasonal FWI score suggests a warming and drying pattern in the mean climate leading to more favorable conditions for wildfire development. On the other hand, understanding changes in the fire weather season length is important for adaptation planning as it indicates for how long regions are at risk of wildfire development. This information is fundamental for an effective allocation of resources to wildfire response units, that might need to be significantly reinforced in drying regions experiencing a significant lengthening of the critical fire weather season.

Risk assessment

In the FWI risk assessment methodology, followed for the case of Aigaleo, the wildfire risk is defined as the combination of wildfire danger and vulnerability. Specifically, in the first step, the wildfire danger is estimated from the combination of climatic danger and the fuel availability which are expressed here with the FWI and the abundance of burnable vegetation respectively. These parameters are normalized and averaged to give a spatialized fire danger index. Then, this index is combined with the vulnerability indicators, namely population at the Wildland Urban Interface (WUI), protected areas fraction, ecosystems irreplaceability, population density and restoration cost to produce the risk index. To do this a Pareto analysis was performed to find which areas across the region have the highest overall risk given the selected indicators. Pareto analysis is defined as "a statistical technique in decision-making used to select a limited number of tasks that produce a significant overall effect. It uses the Pareto Principle (also known as the 80/20 rule), the idea that by doing 20% of the work, you can generate 80% of the benefit of doing the entire job". In our case, the several indices are considered if equal importance and the several tasks are the pixels of the region. Thus, the output of the wildfire risk assessment is a plot that gives an indication of the areas across the region with the highest wildfire risk and how this compares with the climatic danger represented by the FWI.

2.4.Preliminary Key Risk Assessment Findings

2.4.1. Severity

In this section, the preliminary key findings from the workflows for Urban Heatwaves (Section 2.4.1.1) and Wildfire (Section 2.4.1.2) are presented and discussed. Based on these results, the major risks for Aigaleo are identified while their severity and potential impacts are estimated considering historic and current trends.

2.4.1.1 Urban Heatwaves

In Figure 4, the timeseries of annual heatwave occurrence in Aigaleo (37.99°N, 23.68°E) from 1986 to 2085 based on RCP4.5 and RCP8.5 is shown. For the calculation of heatwaves occurrence, the health-related definition was used. According to the results, the annual frequency of heatwaves occurrence in Aigaleo was almost constant during the period 1986-2000 for both RCPs 4.5 and 8.5, while it follows an increasing trend from 2000 to 2085. Following the RCP4.5, the frequence of heatwaves in Aigaleo is expected to reach 25 episodes/year when in 1986 it was 5 episodes/year. Based on RCP8.5, the frequence of heatwaves in Aigaleo will be 40 episodes/year. These results verify that heatwaves constitute one of the major present and future risks for the study region.

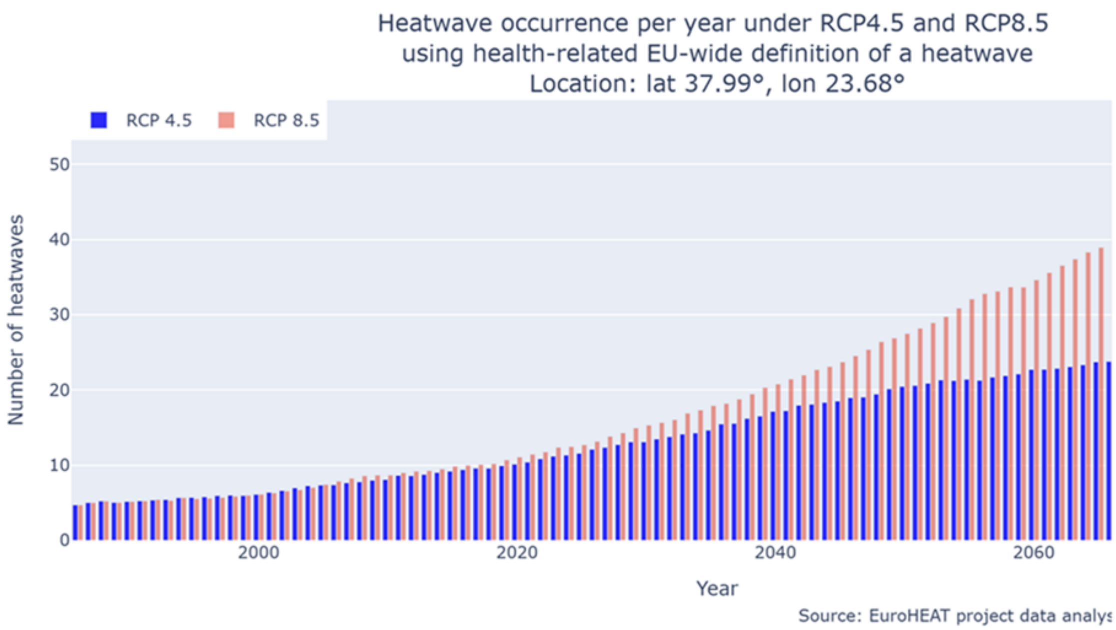
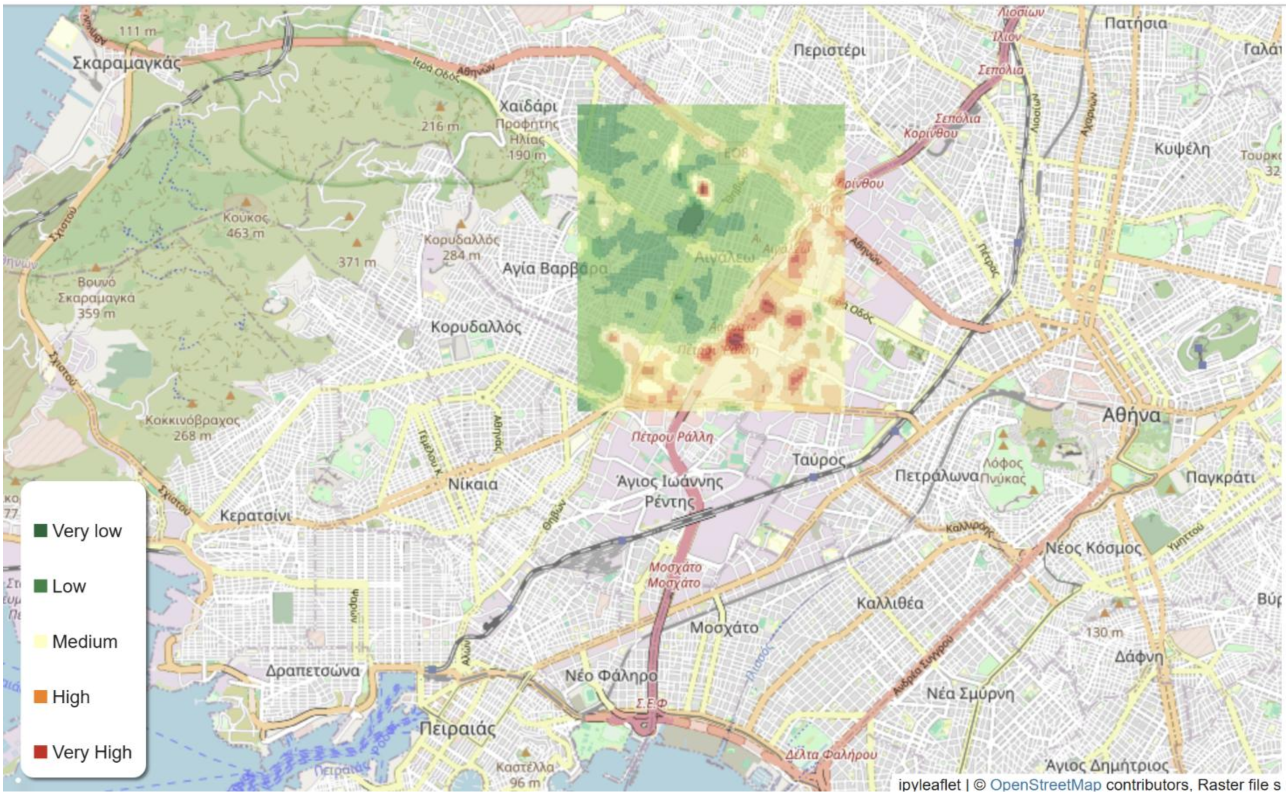
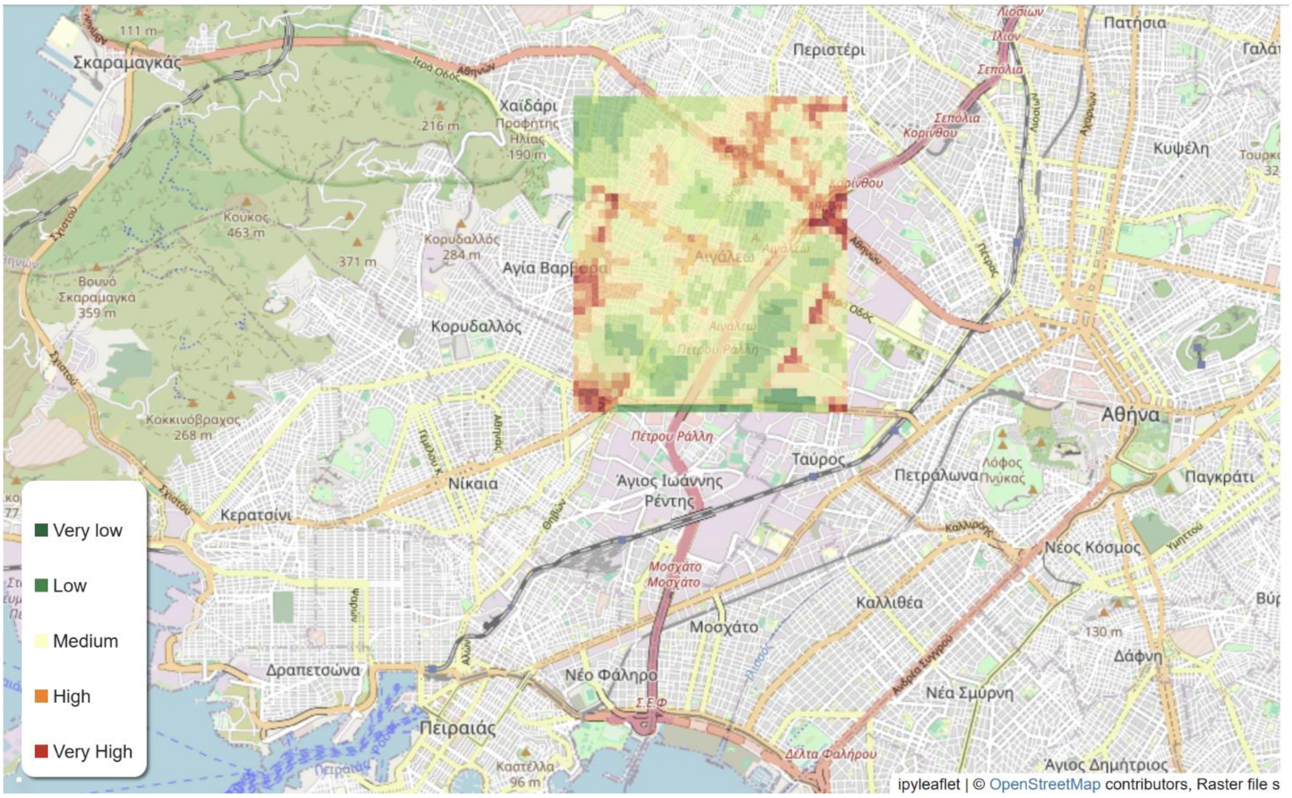


Figure 4. Heatwave occurrence per year under RCP4.5 (blue lines) and RCP8.5 (red lines) using health-related EU-wide definition of a heatwave for Aigaleo (37.99°N, 23.68°E).

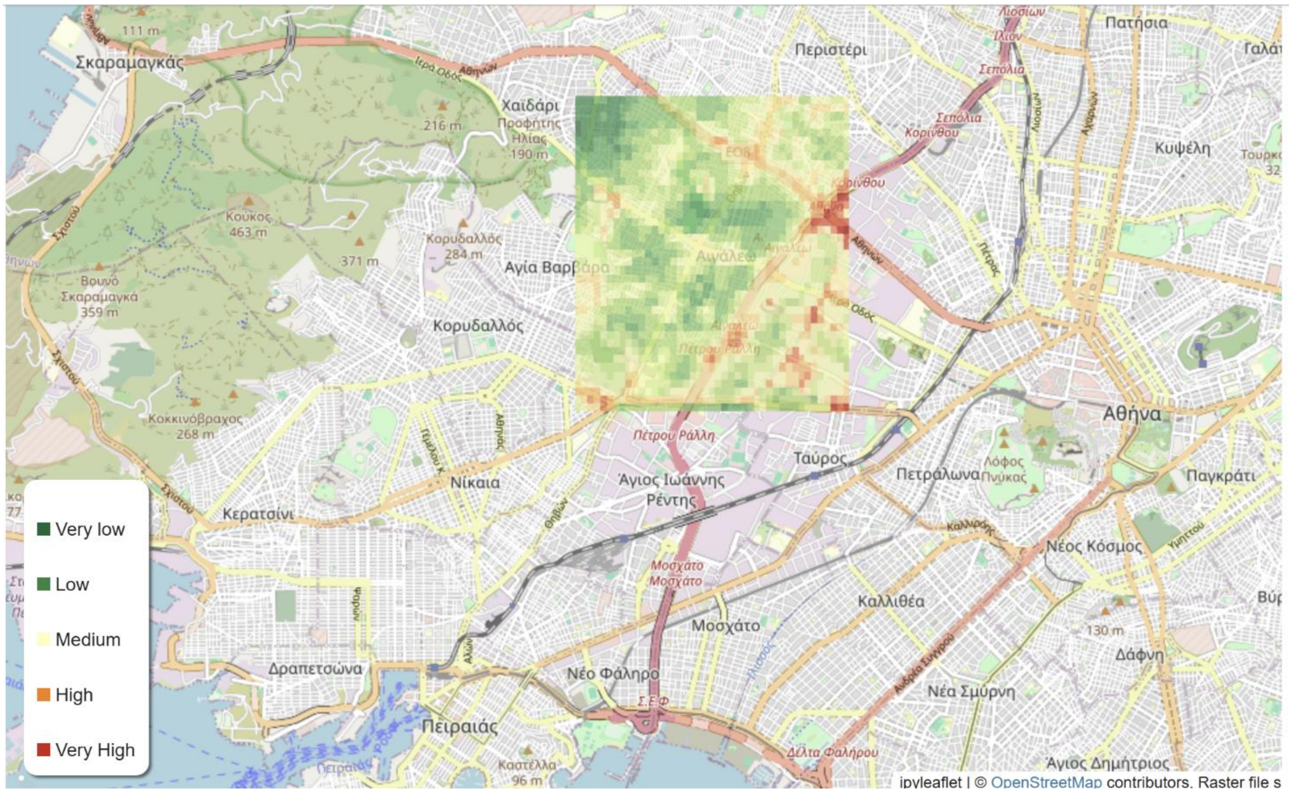
The geographical distribution of heat exposure in Aigaleo estimated based on the LST, is given in Figure 5a. As it is shown in this figure, the most exposed areas are located at the south-eastern parts of the region and especially across the Petrou Rally Avenue (reddish colors). Petrou-Rally is a large central road with high traffic and thus it is expected to reach high LST values. Moreover, an isolated spot of very high exposure appeared at the north-central part of the study region. In this area are located sport facilities mainly constructed by concrete, which can explain the high LST values. For the rest of the region, the heat exposure ranges from low to very low (green colors). In Figure 5b, the geographical distribution of heat vulnerable population using the WorldPop population density is shown. The maximum density of vulnerable population is observed across the large streets, namely Athinon, Iera Odos and Petrou Rally Avenues. This is not realistic and is possibly derived from an error in the used dataset. WorldPop methodology uses a Random Forest model to generate population density predictions based on ancillary data. These data include land cover, elevation data and derived slope estimates, nighttime lights, climactic spatial variation, roads, waterways, settlements, protected areas, and facilities such as schools, hospitals, and health clinics and can vary by country based on data availability and the relative importance for population estimation at each location (Bustos et al., 2020). So, it is possible that the population density is overestimated across the large avenues due to nighttime lights. Last, in Figure 5c, the geographical distribution of the possible heat risk estimated from the summarizing of heat exposure and population vulnerability, is shown. In general, the heatwave risk in the study area ranges from medium (yellow colors) to low (green colors). The highest risk is noted across the large avenues, similarly to the distribution of vulnerable population.



(a)



(b)



(c)

Figure 5. Heat exposure based on LST (a), distribution of vulnerable population (b) and possible heat risk (c) in Aigaleo.

Regarding the geographical distribution of the future heatwave risk, the available workflow provides information for the expected relative change in heatwave risk to the vulnerable population during the period 2016-2045 compering to the period 1986-2015 at NUTS3 level. This is calculated using EuroHEAT hazard data based on the health-related EU-wide definition and vulnerable population data. On the first step, the relative change in annual frequency of heatwave occurrence calculated from the mean values for the selected historical and projections time periods was calculated (Figure 6). According to the results, the entire region of Attica, the frequency of heatwave occurrence is expected to be increased by 46% to 182% for both RCPs 4.5 and 8.5. For Aigaleo which belongs to West Attica subregion, this change is around 90% and 140% based on RCP4.5 and RCP8.5 respectively. Then, the heatwave occurrence relative change data reclassified into 10 equal interval classes (Figure 7). This is necessary to use the data in the 10+10 risk matrix (Figure 3) to calculate the relative change of heatwave risk to the vulnerable population. As it is shown in Figure 7 the relative change for Aigaleo in the scale from 1 to 10 is between 4 and 5 based on RCP4.5 and 6 and 7 based on RCP8.5. At the third step of the workflow, the vulnerable population data extracted and reclassified into 10 equal interval classes (Figure 8), similarly to the heatwave occurrence. According to Figure 8, in Aigaleo, but also in the greatest part of Attica, the vulnerable population density is very high (dark red colors). Last, at the final step, the magnitude of change in the heatwave occurrence combined with the vulnerable population density to estimate the relative change of heatwave risk in the vulnerable population groups. According to the results which are presented in Figure 9, this change is expected to be high and very high based on RCPs4.5 and 8.5 respectively for the greatest part of Attica and also for Aigaleo.

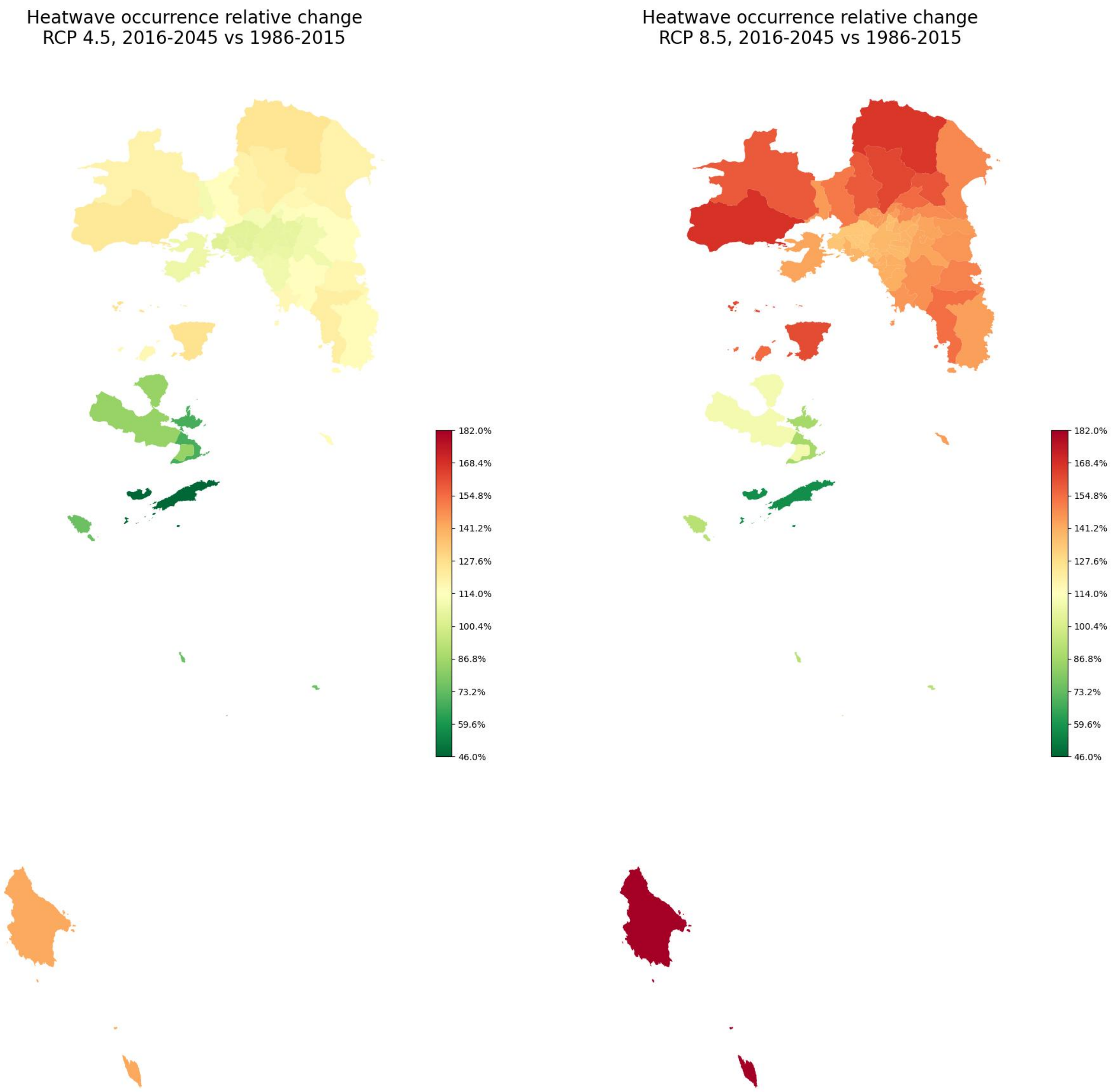


Figure 6. Relative change of heatwave occurrence based on RCP4.5 (left) and RCP8.5 (right) for the period 2016-2045 in reference to the period 1986-2015. Results are given for West Attica.

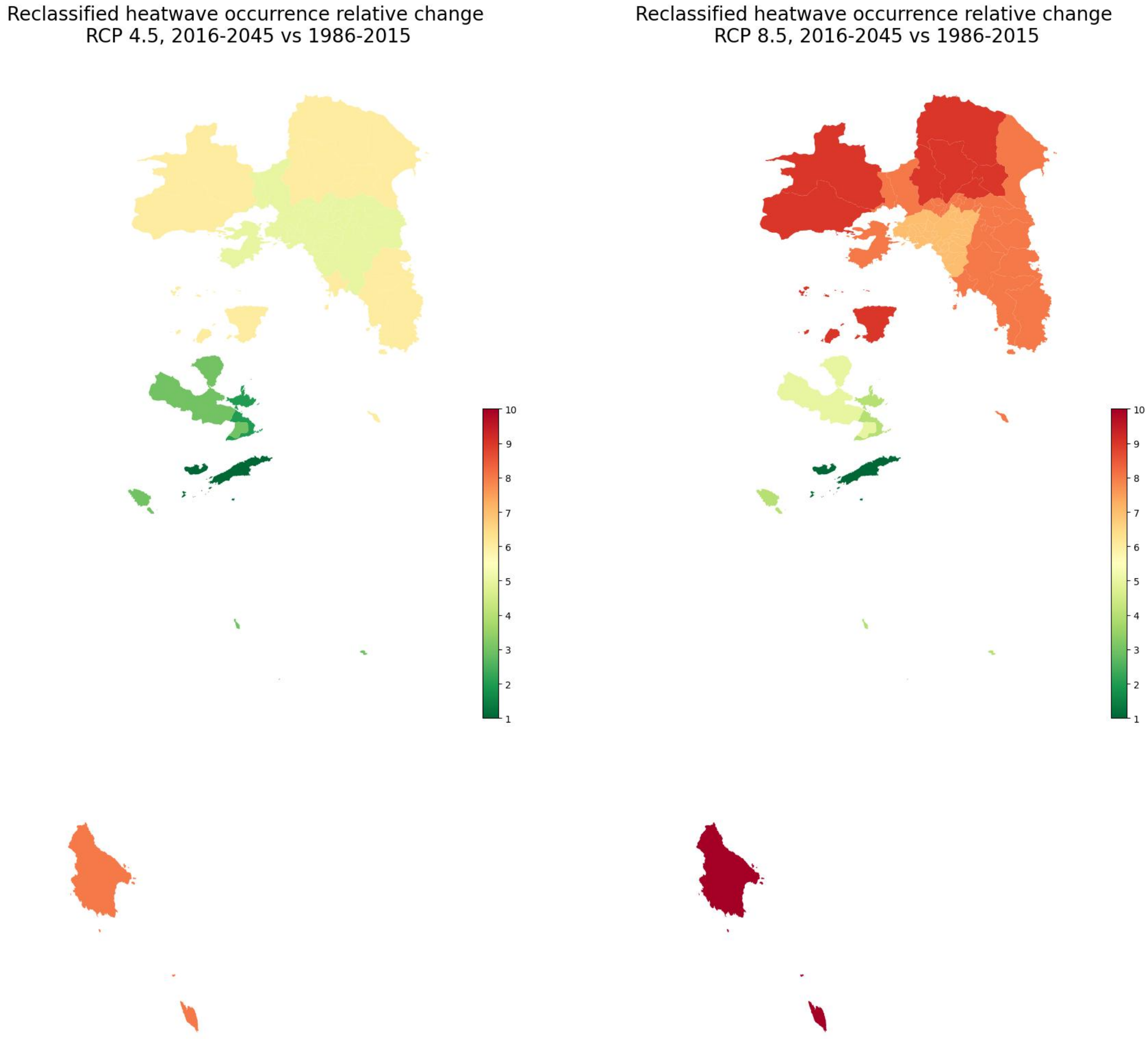


Figure 7. Scaled relative change of heatwave occurrence, based on RCP4.5 (left) and RCP8.5 (right) for the period 2016-2045 in reference to the period 1986-2015. Results are given for West Attica.

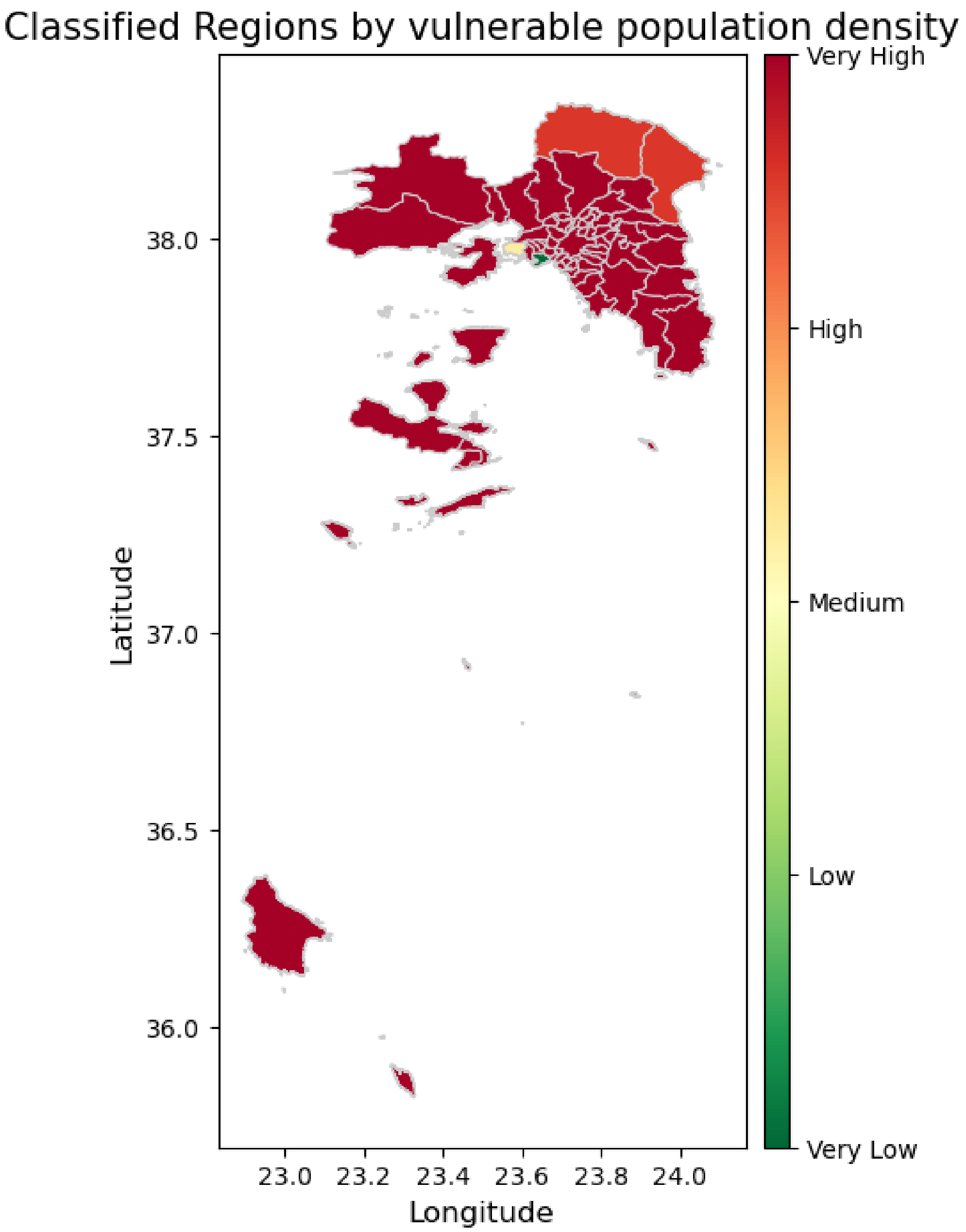


Figure 8. Scaled (from 1 to 10) vulnerable population density in West Attica.

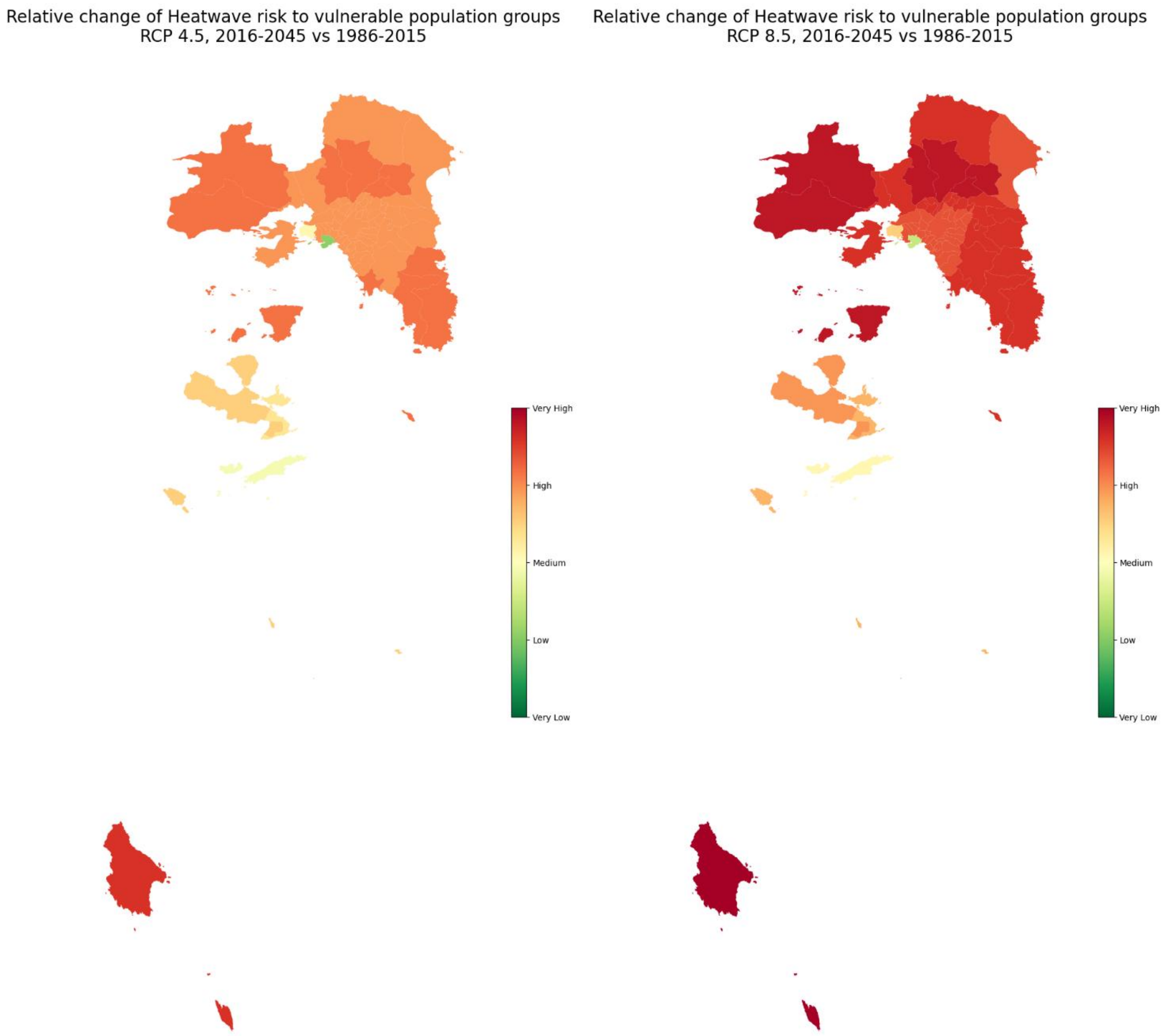
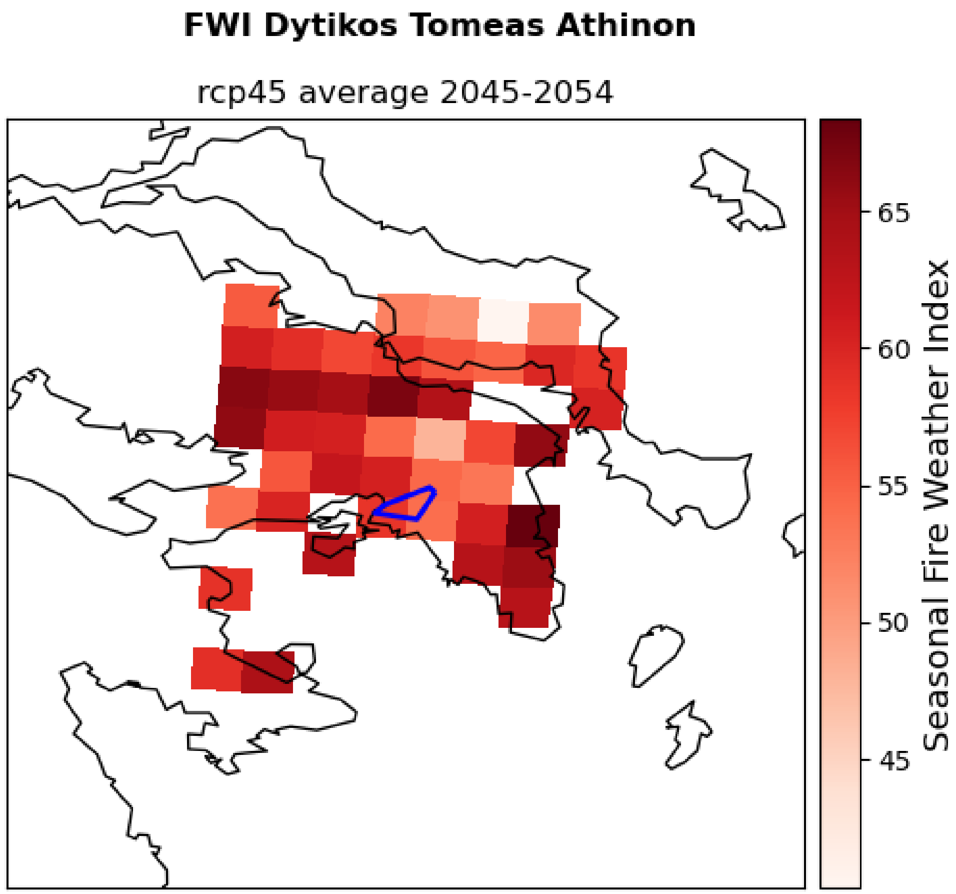


Figure 9. Scaled relative change of heatwave risk to vulnerable population, based on RCP4.5 (left) and RCP8.5 (right) for the period 2016-2045 in reference to the period 1986-2015. Results are given for West Attica.

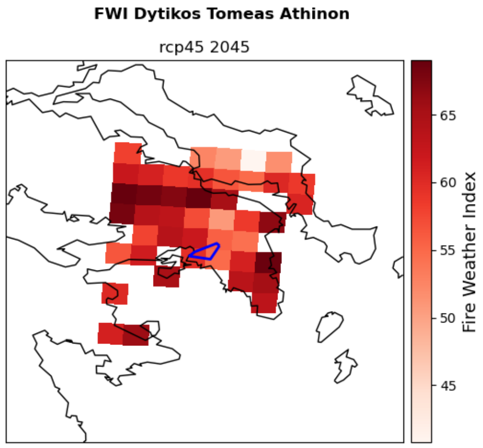
2.4.1.2 Wildfire

As described in Section 2.3.2.1, the wildfire hazard assessment for Aigaleo was conducted based on the spatial and temporal trends in seasonal FWI intensity and to changes in the fire weather season duration and onset based on FWI. In Figure 10, the geographical distribution of seasonal FWI is shown as climatological mean and for each year of the period 2045-2054, based on RCP4.5. The spatial resolution of these maps is very coarse and the features of West Attica and especially for Aigaleo are lost. In general, very high (from 38 to 50) to extreme (>=50) values are expected over the greatest part of Attica. The greatest values (around 68) are observed across the eastern coast of the area, from Sounio to Porto Rafti and the line across Oropos-Oinofyta-Thiva. However, the observed values are very low compared to the existing bibliography (Politi et al., 2023). Concerning the annual mean distributions (Figures 10b-k), there are not significant year to year variations.


FWI Dytikos Tomeas Athinon
rcp45 average 2045-2054
65
60
55
50
45
Seasonal Fire Weather Index

]

(a)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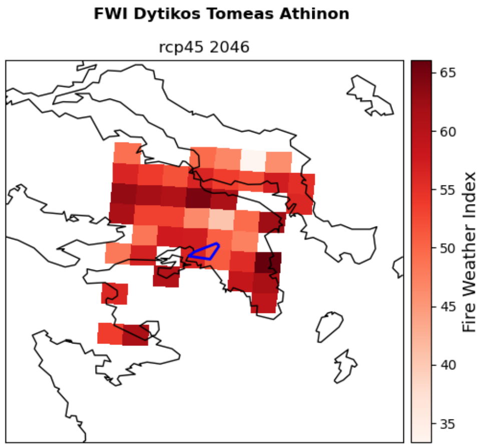
Fire Weather Index

(b)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rcp45 2046
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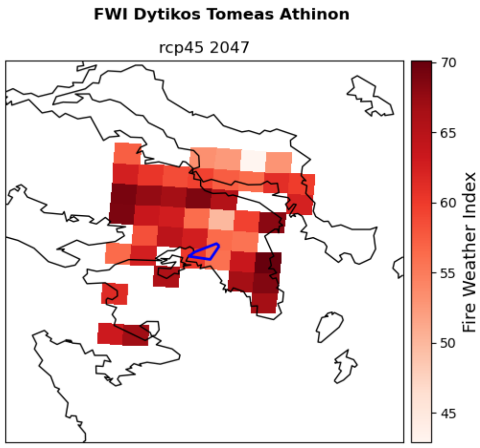
35
Fire Weather Index

(c)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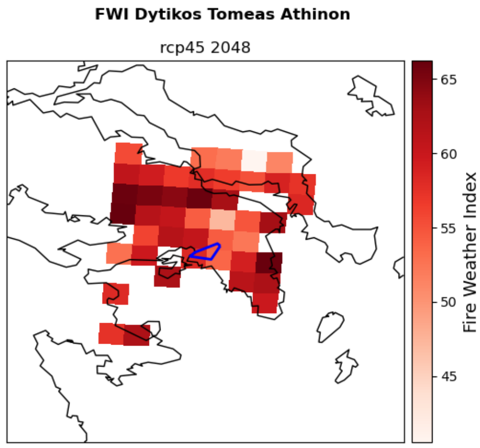
Fire Weather Index

(d)


FWI Dytikos Tomeas Athinon
rcp45 2048
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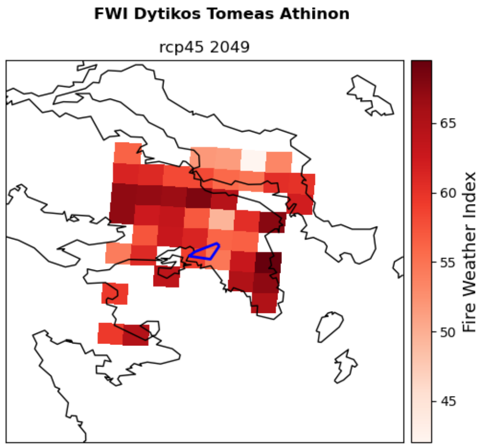
Fire Weather Index

(e)


FWI Dytikos Tomeas Athinon
rcp45 2049
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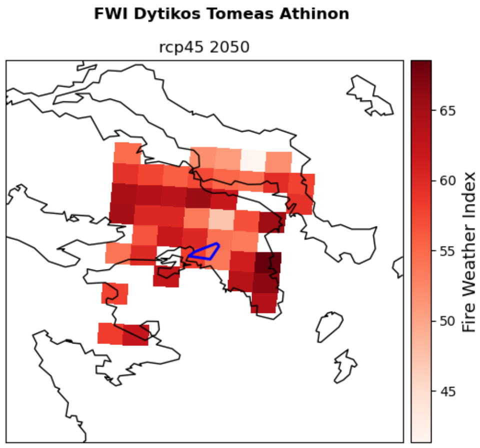
Fire Weather Index

(f)


FWI Dytikos Tomeas Athinon
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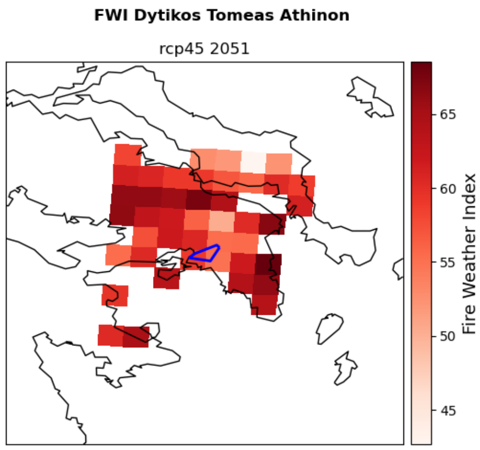
Fire Weather Index

(g)


FWI Dytikos Tomeas Athinon
rcp45 2051
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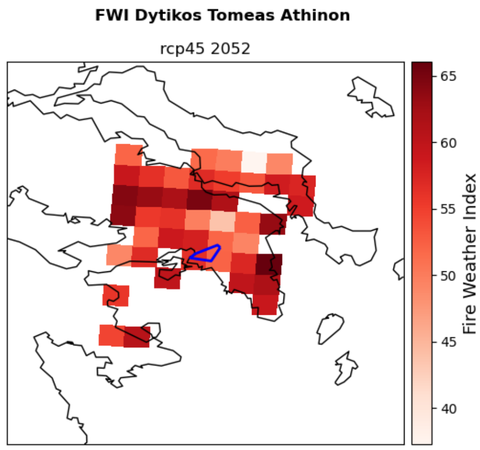
Fire Weather Index

(h)


FWI Dytikos Tomeas Athinon
rcp45 2052
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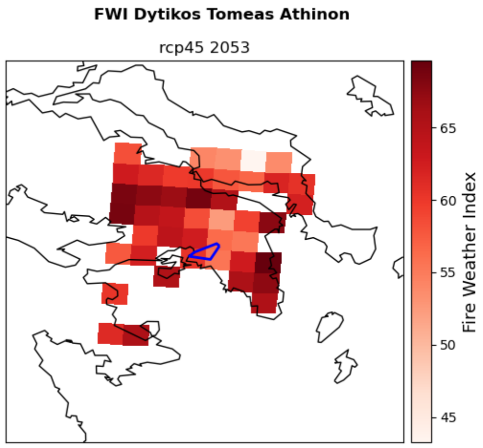
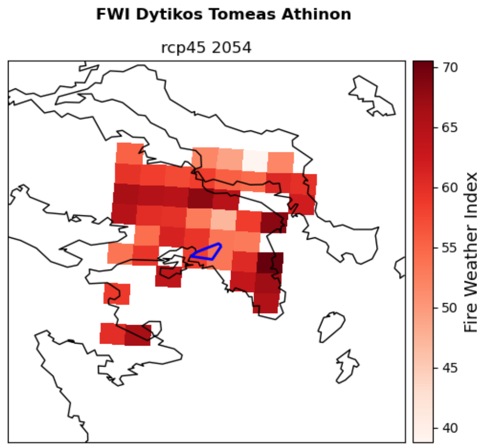
Fire Weather Index

(i)



(j)



(k)

Figure 10. Geographical distributions of (a) the mean FWI of the period 2045-2054 and (b-k) the seasonal FWI of each year of the period 2045-2054, based on RCP4.5. The blue frame includes Dytikos Tomeas Athinon, where Aigaleo is located.

In Figure 11, the geographical distributions of fire weather season length in the historical (1985-2005) and future (2045-2054) periods for Attica are shown. For both periods, “best”, “worst” and “mean” case conditions are presented. The worst- and best-case scenarios are obtained respectively summing and subtracting the inter-model and inter-annual standard deviation of the fire weather season from the mean. This range of possible conditions covers 95% of the possible distribution. In general, very high values are observed for both historical (up to 200 days in the mean case scenario) and future (up to 180 days in the mean case scenario) periods. These values are much higher than those observed in literature (<50 days for the greatest part of Attica) and this due to the low threshold (>30) applied to the FWI, which is not indicative of Greek conditions.

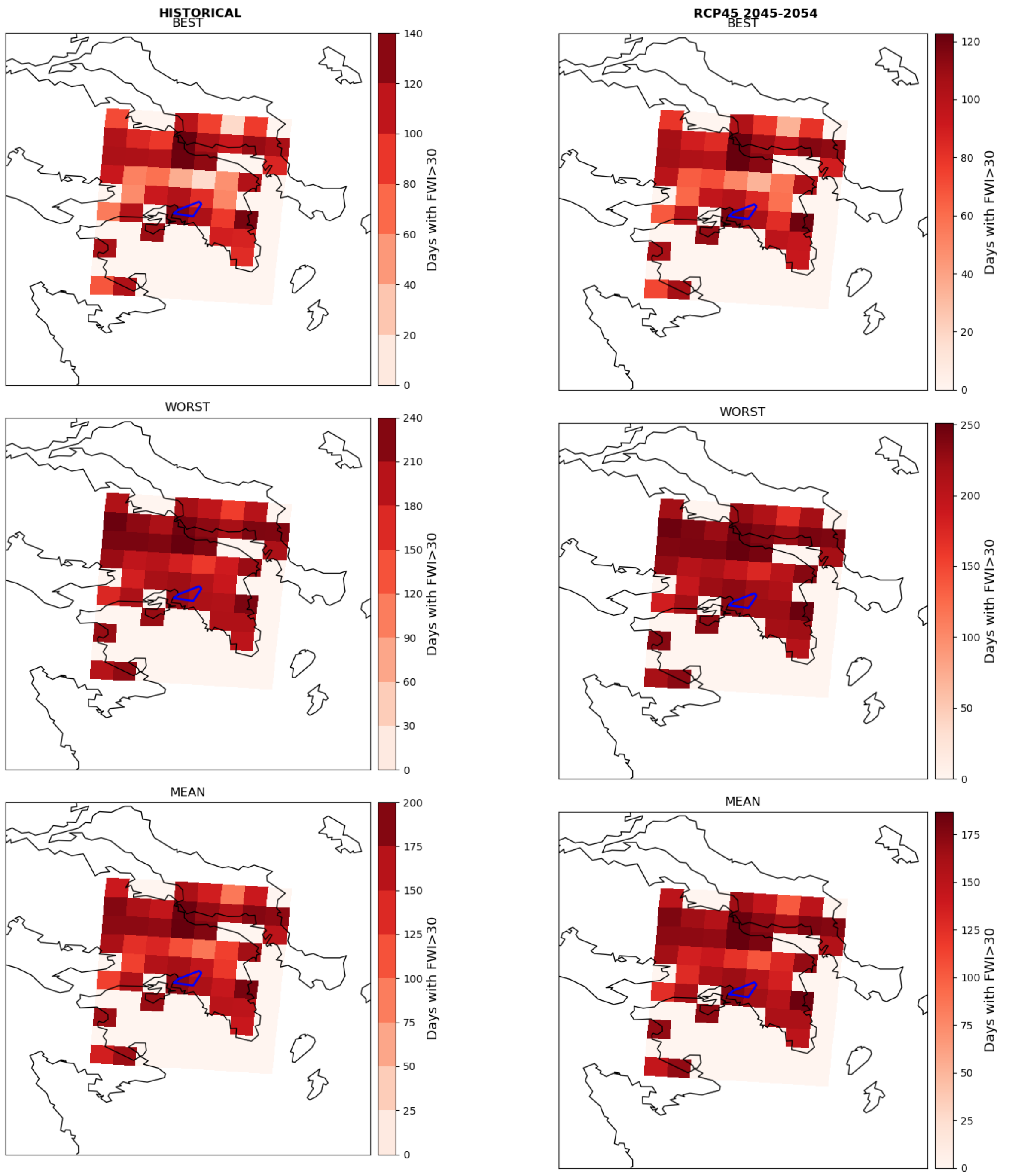


Figure 11. Geographical distributions of the fire weather season length (number of days with FWI>30) for the historical period 1985-2005 (left column) and the future period 2045-2054 (right column) for the greater area of Attica. The best (first row), worst (second row) and mean (third row) case conditions are presented. The blue frame includes the west part of Attica, where Aigaleo is located.

In Figure 12, the geographical distribution of Fire Danger Index (FDI) is shown. In the workflow ran for the risk assessment of Aigaleo, the fire danger is defined as the combination of climatic danger, represented by the seasonal FWI, and the fuel availability, represented by the abundance of burnable vegetation (Figure 13a). These danger indicators are normalized and averaged to produce a fire danger index, which is later combined with a set of wildfire vulnerability indicators (Figures 13b-f) to produce the risk index. The spatial distribution of FDI is strongly affected by the seasonal FWI and

thus appear more similar characteristics with Figure 10a and less with Figure 13a (burnable vegetation).
To assess the vulnerability of Attica in wildfires, several indicators namely Population living in the Wildland Urban Interface (WUI), the existence and the distribution of protected areas, the ecosystem irreplaceability index, the population density and the ecosystem restoration cost index, were used. The geographical distributions of each of these indicators are given in Figures 13b-f. As has already been mentioned, the spatial resolution of the current analysis loses features of Attica. In general, the maximum percentages (up to 41%) of people living in WU areas are observed in the coastal areas of Piraeus, Sounion and Laurium, while at Dytikos Tomeas Athinon, the values range from 20% to 41%. Regarding the percentages of protected areas, the maximum values (yellow colors, 85%) are noted in Mount Parnitha. For the rest of Attica region, the values mainly range from 30% to 60%, while for Aigaleo the percentages are between 40% and 50%. The irreplaceability index values mainly vary between 0.4 and 0.6 in Attica and also in the west part of it. On the other hand, population density became maximum (> 500 people/km^2) in the area of interest (Dytikos Tomeas Athinon,). Last, the restoration cost index varies from almost zero values up to 0.7 in the broader area of Attica and between 0.4 and 0.5 in the area of interest.

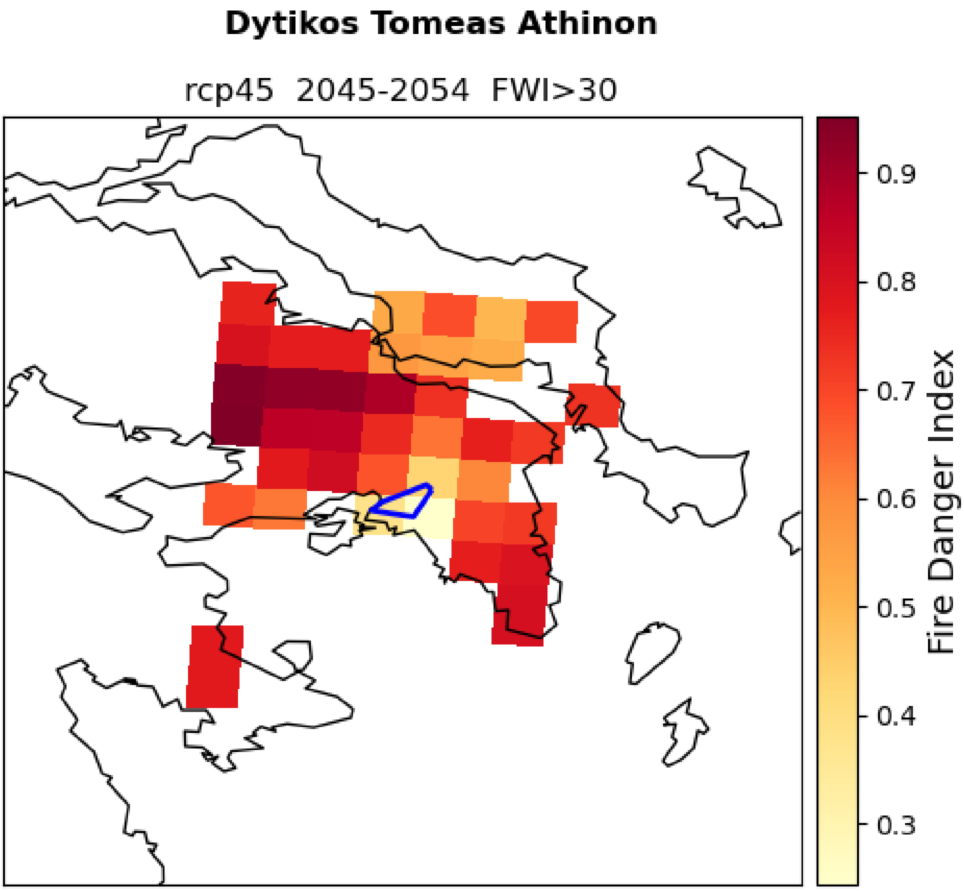


Figure 12. Geographical distribution of Fire Danger Index for the period 2045-2054, based on RCP4.5 over the greater area of Attica. The blue frame includes Dytikos Tomeas Athinon, where Aigaleo is located.

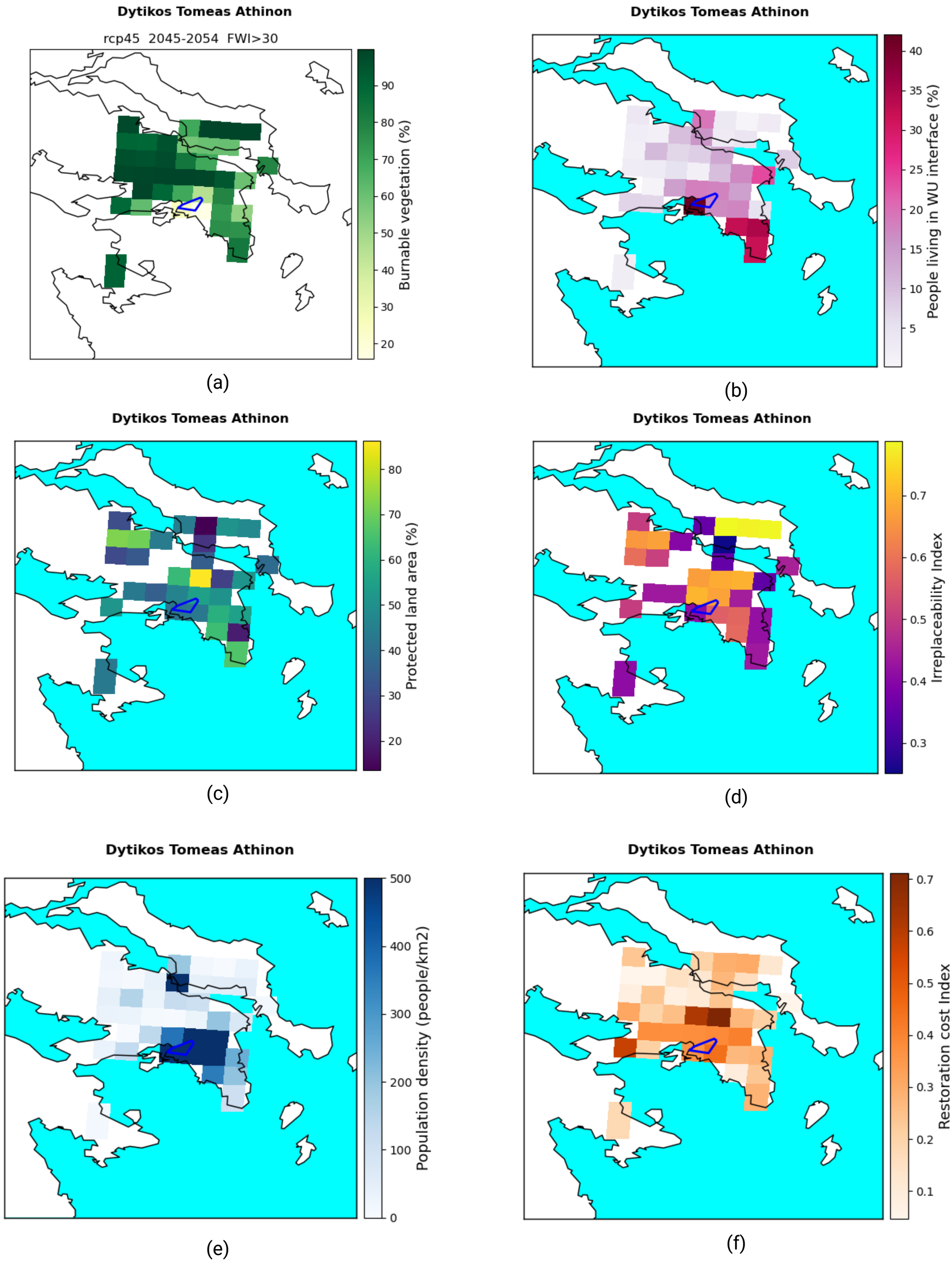


Figure 13. Geographical distribution of (a) burnable vegetation (%), (b) people living in Wildland Urban Interface (%), (c) protected areas fraction (%), (d) irreplaceability index, (e) population density (people/km^2) and (e) restoration cost index for the period 2045-2054, based on RCP4.5 over the greater area of Attica. The blue frame includes Dytikos Tomeas Athinon, where Aigaleo is located.

In Figure 14, the geographical distribution of seasonal FWI (colors) and the fire risk (red and green dots) are shown. The fire risk in this workflow is here calculated from the combination of danger (fire danger index and burnable vegetation) and vulnerability (Population living in the Wildland Urban Interface (WUI), the existence and the distribution of protected areas, the ecosystem irreplaceability index, the population density and the ecosystem restoration cost index) indicators. This is done using the pareto analysis explained in Section 2.3.1.1 of the current deliverable. According to the results, Dytikos Tomeas Athinon is of high fire risk.

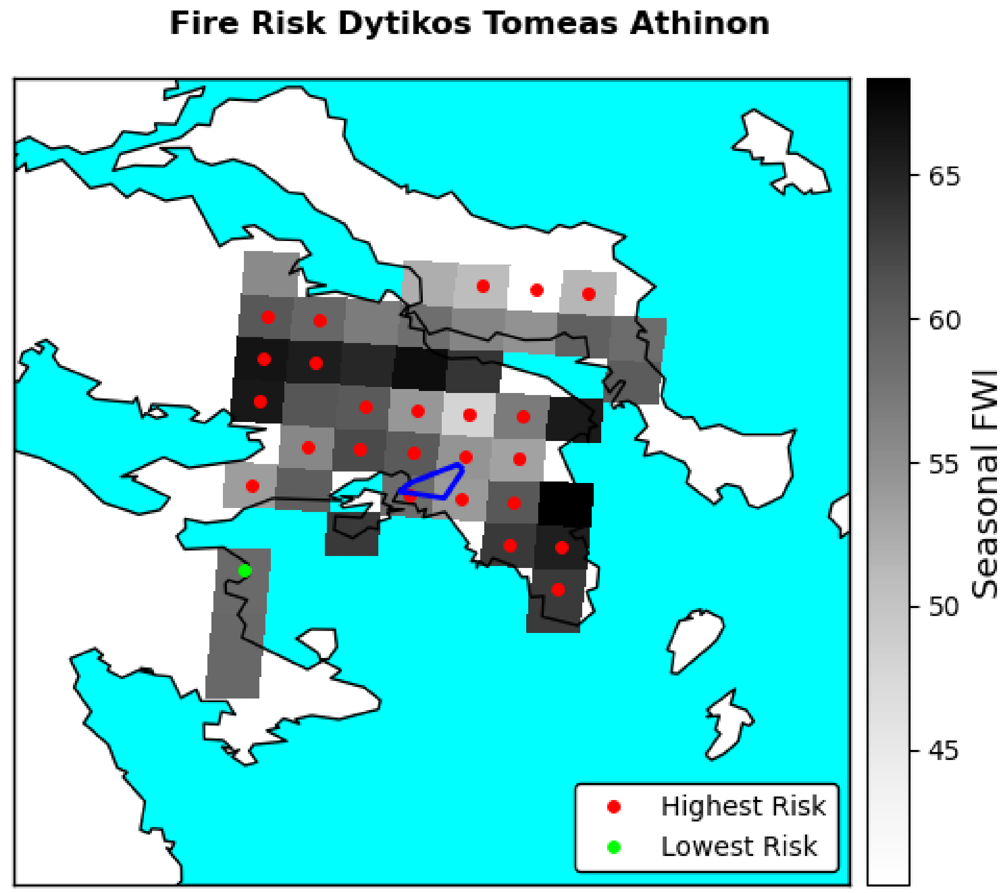


Figure 14. Geographical distribution of seasonal FWI (colors) and Fire Risk (red and green dots) for the period 2045-2054, based on RCP4.5 over the greater area of Attica. The blue frame includes Dytikos Tomeas Athinon,, where Aigaleo is located.

2.4.2. Urgency

The analysis conducted during the first phase of the project was focused on the near future projections, namely 2016-2045 and 2045-2054 for the heatwaves and wildfires respectively. According to the results, the near future risk for both hazards is expected to be high. Specifically, the annual heatwave occurrence is expected to be increased for both RCPs 4.5 (up to 46%) and 8.5 (up to 182%) while a high (RCP4.5) to very high (RCP8.5) increase in heatwave risk to vulnerable population is expected.
On the other hand, based on RCP4.5 during the period 2045-2054 the seasonal FWI is expected to be high (from 55 to 60) in the broader area of Aigaleo. Regarding the fire weather season length, very high duration found for both historical and near future period, while not significant changes are expected. However, these results should be verified with a different FWI threshold, since the threshold of 30 is very low for Greek conditions. The near future fire risk is expected to be high in the area of Aigaleo, based on RCP4.5. This result derived from the expected (i) high FWI values and (ii) high vulnerability indicators.

Based on the abovementioned results which are referred to the near future, the major impact of the risk in Aigaleo will be immediate and so should be the action for minimizing damages.
Within the CLISTHENES project, risks are modelling for both types of hazards: heatwaves and also wildfires have impacts on extremes and also on slow onset events linked to persistent impacts from slow events.

2.4.3. Capacity

AGL has taken significant initial steps toward managing climate-related risks, particularly those associated with extreme heat and wildfires. These existing capacities span financial, social, human, physical, and natural dimensions, although they remain fragmented and often limited by institutional and resource constraints.

In terms of financial capacity, Aigaleo has successfully mobilized funding through its participation in several European projects such as *TransformAr*, *BIN2BEAN*, *C2IMPRESS*, *Rock the Block* and the most recent *Med-IREN* and *ClimateAdapt4EOSC*. These projects have allowed the municipality to pilot innovative solutions — such as citizen awareness tools, early warning systems, and nature-based solutions — while building administrative experience in managing climate funds. However, the municipality still depends largely on external funding sources due to the limited autonomy and fiscal flexibility of local governments in Greece (Municipality of Aigaleo Strategic Plan 2024–2028, Section 3.4).

Social capacity is supported by a network of active local organizations, volunteers, and municipal services that collaborate in civil protection, social care, and educational initiatives. Past participatory processes — including C2IMPRESS workshops and TransformAr pilot actions — have helped raise awareness and foster dialogue around climate vulnerability, particularly among teachers, caregivers, and community-based groups. Yet, long-term community engagement structures are still in development, and social capital has been weakened in recent years by economic hardship and pandemic-related fragmentation (Strategic Plan, Sections 1.3.6 & 1.4.2).

Human capacity exists primarily within the municipality's civil protection, technical works, and social services departments. Staff members have been trained in the CLIMAAX methodology (20 people as of Month 3 of the project), and interdepartmental coordination has improved through cross-sectoral meetings. Nevertheless, limited staffing and high administrative workloads often hinder the consistent application of climate risk approaches in day-to-day governance.

On the **physical level**, critical infrastructure remains vulnerable. While Aigaleo has developed a Sustainable Energy and Climate Action Plan (SECAP), most public buildings still require energy efficiency upgrades, and many neighborhoods lack sufficient green cover or cooling infrastructure. Road networks and stormwater systems in certain districts — especially near Eleonas and along the Kifissos Avenue — are outdated or under-dimensioned, increasing exposure to both heat and flooding risks (Strategic Plan, Section 1.2.4).

Natural capacity is constrained by the municipality's high degree of urbanization, with limited open space. However, areas such as the **Aigaleo Grove** and **Mount Aigaleo** offer valuable green infrastructure that can be preserved and enhanced for climate adaptation, fire prevention, and community well-being.Despite these limitations, several opportunities emerge from addressing climate risks in a more integrated and forward-looking way:

- Financially, the development of a robust Climate Risk Assessment can unlock new funding opportunities at the national and EU level, by improving the municipality's project readiness and strategic alignment.
- Socially, engaging vulnerable groups in co-design processes fosters inclusion, trust, and community cohesion, while building climate literacy from the bottom up.
- Human capacity can be expanded through continued training, horizontal knowledge sharing, and institutional learning — especially with the involvement of academic partners such as NCSRD and the University of West Attica.
- Physically, adaptation interventions can support a transformation of public space — through urban greening, shading, and bioclimatic design — improving not only resilience but also quality of life.
- Naturally, investing in the restoration and protection of existing green areas can act as both a mitigation and adaptation strategy, enhancing biodiversity, water retention, and thermal comfort.

Through the CLIMAAX project, Aigaleo has the opportunity to consolidate these existing capacities and create a more coherent, data-informed, and community-rooted strategy for long-term resilience.

2.5. Preliminary Monitoring and Evaluation

During the first-phase of climate risk assessment, a first overview of the existing and/or expected heatwave and wildfire risk was made. The main difficulties raised during this period are connected to the training of nonscientific staff on workflows. It is quite difficult for a person with zero programming experience to understand and operate the codes.
The feedback received from stakeholders was overall positive and focused on the following:

1. The risk assessment process is straight-forward and gives results which can be easily interpreted
2. The results do not seem to follow local patterns, especially for vulnerable groups. Local information is available and could be used
3. The workflows are impossible to implement (due to lack of programming / python language). Most viable way to implement them is through external subcontracting for external experts

- Regarding the data, most of the available data in the workflows are available on a low spatial resolution and thus they are not appropriate for small regions such as Aigaleo. Moreover, the population data from WorldPop do not make sense given that the greatest values of population density appear on the high avenues. So, it is important to have consistent data on high spatial resolution. Moreover, although several useful wildfire vulnerability data are used in FWI workflow, there is not available a detailed description of them. This is important for the user in order to be able to trust the dataset and then interpret the results. Last, it is important, for consistency reasons all workflows study the same historical and future periods.
- Most of the data used in the first phase of the project are available on coarse spatial resolution and thus they lose features of Attica and especially of the even smaller region of Aigaleo.
- WorldPop data used in the Heatwaves workflow overestimate the population density across the high avenues and it seems that they cannot catch the local population distribution.
- The vulnerability data used on wildfire workflow are not well described and it is difficult to find information about the data production.

- The CRA results for heatwaves and wildfires are not directly comparable, and consistency needs to be achieved for prioritizing risks within the same area. The scales and methodologies are not identical even for same groups of people (e.g. vulnerable groups) and timeframes.
- The long term patterns from wildfires and impacts from historic events can;t be easily reproduced, as a wildfire spreading model is not present.

3. Conclusions Phase 1- Climate risk assessment

The main conclusions reached in the first project phase can be summarized as follows:

Aigaleo appears to be impacted by heatwaves and wildfires and the defined patterns relatively follow percpetions and local expectations. However, the generated data appear to have a difference to expected exposure on the examined scales

- The CRA and the results are not directly comparable, and consistency needs to be achieved for prioritizing risks within the same area
- The long term patterns from wildfires and heatwaves can;t be addressed directly. Wildfires have an xtremely coarse resolution for the scales of Aigaleo.

It is difficult to train stakeholders with zero programming background to run the workflows. Maybe a more automated tool should be created.

- In particular, for heatwaves risk on vulnerable population in Aigaleo, the region already experiences medium to high risk based on the historical analysis. In the near future period (2016-2045) heatwaves occurrence is expected to be increased based on both RCPs 4.5 and 8.5. This will result to a high to very high increase in heatwave risk to vulnerable population.
- On the other hand, from the wildfire's workflows, it is found that based on RCP4.5, seasonal FWI is expected to be high (55-60) in the broader area of Aigaleo, during the period 2045-2054. For the duration of fire weather season, it is difficult to take a conclusion since the proposed threshold of FWI>30 is not indicative of Greek conditions. The fire risk for the same period is expected to be high, based on RCP4.5.
- In general, the results (both for heatwaves and wildfires) provide a very coarse overview of the greater area of Attica and Aigaleo, but they cannot depict the local patterns due to the low spatial resolution of the input data.

4. Progress evaluation and contribution to future phases

CLISTHENES KPI are presented in Table 1.

Table 4. Overview milestones

Milestones	*Progress*
M1: Successful implementation of the training sessions (M3, P1)	Completed
M2: Completion of P1.6 (M6, P1)	Completed
M3: Localized CLIMMAX Methodology (M15, P2)	Not started
M4: Production of A3.1 (M16, P3)	Not started
M5: Creation of the interventions and policies of PHASE 3 (M22, P3)	Not started
M6: Completion of A3.4 (M21, P3)	Not started
M7: Attend the CLIMAAX workshop held in Barcelona. (M8, P2)	Not started
M8: Attend the CLIMAAX workshop held in Brussels (M15, P2)	Not started

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