CLIMAAX
climate ready regions

Deliverable Phase 1 – Climate risk assessment

Assess Multiple Climate Risks in Attica Region and improve Adaptation Strategy and Risk Management Plans using CLIMAAX Framework and Toolbox (AtticaReAdy)

Greece, Region of Attica

Version 3.0 | March 2025

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.

1. Document Information

Deliverable Title	Phase 1 – Climate Risk Assessment
Brief Description	This deliverable describes Phase 1 of Climate Risk Assessment for the Region of Attica using the toolbox of CLIMAAX. There are described also the steps of scoping, risk exploration and risk analysis concluding with preliminary key risk assessment and monitoring and evaluation. The climate risk assessment was done for the fluvial floods and wildfires.
Project name	AtticaReAdy: Assess Multiple Climate Risks in **Attica Re**gion and improve **Ad**aptation Strateg**y** and Risk Management Plans using CLIMAAX Framework and Toolbox
Country	GREECE
Region/Municipality	REGION OF ATTICA
Leading Institution	Autonomous Directorate of Civil Protection Directorate of Environment and Climate Change
Supporting subcontracting Institutions	-
Author(s)	• Dr Chalari Ioanna (Directorate of Civil Protection) • Dr Parapouli Maria (Directorate of Environment and Climate Change)
Deliverable submission date	29/03/2025
Final version delivery date	31/03/2025
Nature of the Deliverable	R – Report;
Dissemination Level	PU - Public

Version	Date	Change editors	Changes
1.0	05/03/2025	All Authors, RoA	First version ready for internal review
2.0	14/03/2025	Dr Nikos Passas, RoA	Internal review completed
3.0	29/03/2025	All Authors, RoA	Reviewed version submitted
		CLIMAAX's FSTP team	Review completed
5.0	…		Final version to be submitted

2. Table of contents

3. List of figures

4. List of tables

5. Abbreviations and acronyms

Abbreviation / acronym	Description
CCAP	Climate Change Adaptation Plan
CoP	Community of Practice
CP	Civil Protection
CRA	Climate Risk Assessment
DRM	Disaster Risk Management
EU	European Union
FWI	Fire Weather Index
GDP	Gross Domestic Product
HNMS	Hellenic National Meteorological Service
KEMEA	Greek Center for Security Studies
NRA	National Risk Assessment
NSCA	National Strategy for Climate Adaptation
RCCAP	Regional Climate Change Adaptation Plan
RCP	Representative Concentration Pathways
RoA	Region of Attica
UNDRR	United Nations Office for Disaster Risk Reduction

6. Executive summary

The AtticaReAdy sub-project, part of the CLIMAAX project under the Horizon Europe program, aims to assess climate risks in the Attica Region of Greece and enhance adaptation strategies and risk management plans. The project leverages the CLIMAAX Framework and Toolbox to conduct a transparent and harmonized Climate Risk Assessment (CRA). This deliverable outlines Phase 1 of the CRA, focusing on scoping, risk exploration, and analysis for fluvial floods and wildfires, combining available datasets in the workflows with stakeholder insights while setting the groundwork for future phases.

While Attica has existing policies (e.g., Regional Climate Change Adaptation Plan, Civil Protection Plans), gaps remain in participatory governance, local data resolution, capacity building and financial resources for resilience-building. AtticaReady sets the objectives and defines the steps towards a resilient region including the opportunity for achieving the goal through participation in other programs (eg P2R).

The key findings for the wildfire risk reviled that rising temperatures and prolonged droughts project a 175-day fire weather season by 2050 especially in Southern Attica, classified as "extreme to very extreme" danger, and also that high-risk zones overlap with wildland-urban interfaces, exacerbating threats to densely populated areas. As far as the fluvial funding key findings is concerned the Kifisos River basin faces inundation depths exceeding 3 meters under RCP8.5 by 2080, with severe economic and social impacts in urban hubs like Piraeus and that residential areas dominate the basin, amplifying vulnerability due to aging infrastructure and population density. Both hazards were classified as "severe and urgent", driven by projected worsening under climate change, insufficient adaptation measures, and cascading socio-economic impacts.

A Community of Practice (CoP) was established with municipalities and regional authorities to validate findings and prioritize actions. Stakeholder feedback highlighted the need for holistic, multi-hazard approaches and improved public awareness. A number of indicators for monitoring, was set including economic damages, fire weather season length, and flood thresholds.

Phase 1 established a robust foundation for climate resilience planning in Attica, highlighting the critical need for proactive, science-driven strategies. The CLIMAAX Toolbox proved effective in risk profiling, though localized data and stakeholder collaboration remain pivotal for actionable outcomes. By prioritizing multi-hazard synergy and participatory governance, the project aligns with EU climate resilience goals. This first phase encapsulates the urgency of addressing climate risks in Attica, underscoring the transformative potential of harmonized technical tools and collaborative governance to safeguard communities and ecosystems.

The need for enhanced data integration through incorporation of local, high-resolution datasets to refine risk assessment was reviled. This will be the focus during next phase including also the possibility to extend the risk assessment for heatwaves, and droughts that were noted as exacerbating factors, necessitating multi risk assessment and also to empower municipalities and improve risk communication.

1 Introduction

1.1 Background

Region of Attica (RoA) is a self-governed public body, second-level local government organization of the Hellenic Republic, comprising of 8 regional units, 66 municipalities among which are 8 islands. Attica stands as Greece's most populous and densely inhabited region and encompasses the urban conglomerate of Athens, which serves as the nation's capital. Attica's population exceeds one-third of the total national population, 3.792.469 residents out of a nationwide total of 10.432.481 (2021 census).

RoA plans and implements policies at regional level and is responsible according to Law 4936/22 to execute the Regional Climate Change Adaptation Plan (RCCAP) and implement the proposed adaptation measures. RoA coordinates according to its territorial competence Civil Protection actions regarding prevention, preparedness, disaster response and implementation of relief actions (Law 4662/2020).

Attica produces approximately 48% of the country's total GDP and maintains its dominant position in the national economy. Regarding the Gross Added Value, the Region of Attica in the primary sector, participates with only 4,35%, in the secondary sector, it holds a large share with 33.38% and in the tertiary sector, it holds the largest share with 47,20%.

In the field of health is the center of the main volume of the country's health and welfare services. It brings together approximately 31% of the country's hospital units. At the level of infrastructure, the central airport and the system of the ports of Attica, with the port of Piraeus being the most important, are the main gateways of the country, bringing into contact with the global production network and citizen/visitors. The cultural resources of Attica are particularly remarkable both in terms of their importance and in terms of their number and variety. These cultural resources are distributed throughout the region and are of unique value in a global and national context.

The current state of the urban natural environment has as its main characteristics the unplanned residential expansion, the traffic problems, the deficient urban and peri-urban greenery and the lack of open public spaces, which are important and constantly worsening problems. Attica is particularly vulnerable to high-impact weather events as it has faced extensive deforestation and urbanization over the years. The latest scientific indicators indicate that the Mediterranean and, by extension, Greece, represent one of the hotspots of the evolving environmental crisis. Inevitably, the Metropolitan area of Attica cannot be exempt from this new reality. The emergence of new forms of risks and crises, the occurrence of more extreme events, the larger scale of disasters, the complexity and intricacy of hazards and crises, and the appearance of risks during ongoing disasters and crises are just a few of the new challenges that must be immediately integrated into the operational planning of the region.

RoA faces a spectrum of climatic and geophysical risks, including floods, wildfires, droughts, heatwaves, landslides and earthquakes. This high-risk profile necessitates urgent and robust disaster preparedness, adaptation and mitigation efforts. According to the results of the studies on the vulnerability assessment and the impact of CC in Greece conducted by the Bank of Greece, RoA shows the highest vulnerability based on size and population density regarding wildfires. Only the city of Athens hosted a remarkable 5.72 million tourists from around the world for the year 2018, amplifying the already heightened degree of vulnerability. RoA has witnessed a distressing loss of its forests, amounting to 33% in the last seven years. 405.000ha out of 1.230.000ha of forested areas have succumbed to wildfires, constituting 33% of the total forest area. Moreover, its urban character intensifies the annual heatwaves. Rising temperatures and urban heat islands increase the risk of illness and even death mainly to the most vulnerable residents. Taking into consideration the fatal floods of the recent past, the population density and the percentage of households that the CC impacts will seriously affect their wellbeing, flood is another major risk for the region. Based on the above fact heatwaves, floods, drought and wildfires can be considered the major risks for RoA. These challenges call for new tools and new approaches in the realm of Civil Protection and Climate Adaptation.

1.2 Main objectives of the project

The climate of Greece, and the rest of the world, is changing. Average temperatures have been steadily rising since the 1960s while the decade from 2008 to 2017 was the hottest on record. As the average temperature rises and long-term weather patterns change, the occurrence of extreme weather increases. This means that the assumptions on which cities, towns and regions are planned and run must be reassessed. As time passes new information will come to light improving our understanding of the expected changes in climate and how they will affect us, reinforcing the need to regularly reassess the risks these changes pose.

Climate risk assessment (CRA) assesses the extent to which climate-related risk impacts on people, assets, value chains, infrastructure, and ecosystems. This leads to a better understanding of climate risk, and the initiation of effective action. Obviously, CRAs are increasingly important for ensuring that development is climate-resilient and sustainable. They form the basis for more targeted risk management, including risk-informed decision-making and planning in the context of climate change.

The major purpose of assessing climate change risk is to help prioritize possible adaptation measures that maybe feasible. Some measures, such as no-regrets options, or generic measures that will provide adaptation benefits in a broad range of plausible circumstances, will prove to be better than others. This applies to the development of adaptive capacity in particular. A detailed knowledge of both current and future hazards, and how they may affect societies, can help provide guidance for adaptation and disaster management plans.

Again, given the levels of uncertainty that accompany assessments of future climate risks, we will need determine how much information is needed in order to make decisions on adaptation policy. If policy makers have significant demands, we aim through the project to be able to inform them of the resources needed to meet those demands, including the resources needed to develop assessment methods.

Concluding the main objective of the project is to better understand, prepare for and manage climate risks and opportunities, by an accurate assessment and evaluation of climate risk profiles in order to build locally operated risk management capabilities and develop risk management plans and adaptation measures and ensure that the region will be resilient. In order to achieve this main objective is crucial to work focusing also in more specific objectives.

SO1: Assess the impact of climate change on hazards and explore regional climate risks.

SO2: Revise and refine emergency risk management plans and adaptation measures.

SO3: Build local capabilities on risk management

1.3 Project team

AtticaReAdy exploited the use of the tools of CLIMAAX for Phase 1 with the engagement of the region's staff from Autonomous Directorate of Civil Protection and Directorate of Environment and Climate Change; that have experienced scientists from different fields and the mandate to execute the Regional CCAP (Law 4936/22), the DRM Plans and civil protection actions regarding prevention, preparedness, disaster response and implementation of relief actions (Law 4662/2020).

The team that worked during Phase 1 consisted of:

- Dr Passas Nikos, Geologist, Head of the Directorate of Civil Protection with years of experience in Disaster Risk Assessment and Management
- Akrivos Constantinos, Engineer, Head of the Directorate of Environment and Climate Change with years of experience on Environment and Climate Change Adaptation.
- Dr Chalari Ioanna Chemist, Officer of the Directorate of Civil Protection with climate, environment and disaster management knowledge
- Dr Parapouli Maria Chemist, Officer of the Directorate of Environment and Climate Change with climate and environment knowledge
- Msc Paparrigopoulos Thodoris, Engineer, Officer of the Directorate of Civil Protection with data processing skills and experience from his participation in a number of European projects.

1.4 Outline of the document's structure

The results of the CRA for the Region of Attica are presented in this document using the CLIMAAX Toolbox and European large-scale data (Phase 1). The structure of the document follows CLIMAAX Framework which consists of a five-step assessment cycle starting with Scoping in Section 2.1 presenting the objectives and the context in brief. In section 2.2 Risk Exploration is analyzed focusing on the selection of main hazards, the selection of the workflows and the more relevant scenario for RoA. Scoping, Risk Exploration and Stakeholder Engagement have been analyzed with more details in Milestone 1, a dynamic document that is intended to be enriched also during Phase 2 of AtticaReady, mainly with lessons-learnt from the stakeholder engagement. In Section 2.3 a description of how the selected workflows from the CLIMAAX Handbook were applied to Attica is included. The hazard assessment and the risk assessment are described using the fluvial flood and the wildfire (FWI) workflows. The final two steps of the CLIMAAX Framework are presented in Sections 2.4 and 2.5, preliminary key risk assessment and preliminary monitoring and evaluation since these two steps will be analyzed in more executive way in the following phases. Conclusions of Phase 1 are presented in Section 3, the evaluation of the progress of the project in terms of KPIs is taking place in Section 4 and a list of the supporting documentation in Section 5.

2 Climate risk assessment – phase 1

The effects of climate change are already being felt today: According to the latest climate projections, extreme weather events are set to increase in frequency and magnitude in the future. These events, such as heatwaves, prolonged droughts and floods, along with sea level rise and desertification, and the resulting socio-economic aspects pose a growing risk to the sustainable development of all regions and can lead to economic and non-economic losses and damages. Regions, municipalities and small islands not well prepared are particularly vulnerable to such risks, meaning that their natural and social systems are more exposed to the negative impacts of climate change. Assessing and managing risks in order to avert, minimize, and address loss and damage is therefore of central importance.

2.1 Scoping

Climate Risk Assessment will build the foundation for Disaster Risk Management (DRM) and Climate Change Adaptation Plans (CCAP) in Attica by identifying the nature and extent to which climate change and its impacts may harm the region, a specific sector or the community. Quantifying and assessing climate risk, i.e. the result of the interaction of vulnerability, exposure and hazard, is important to support decision-making and future planning. Thus, the identification of current and future key risks and impacts on people, assets and ecosystems can help to allocate resources accordingly, in order to design adaptation policies and projects for reducing vulnerability and risk, and to establish a baseline against which the success of adaptation policies and actions can be monitored.

2.1.1 Objectives

The main objective of the CRA is to minimize the potential losses and damages in human and ecological systems of the region and support decision-making and planning by taking into account existing goals, values, and the existing policy and planning framework. By understanding the key risks, underlying risk drivers, identifying specific areas and systems most at risk the purpose is to prepare the ground for DRM and CCAP focusing on the hotspots that the CRA will reveal.

CRA is expected to benefit also the 66 municipalities of the region of Attica by raising awareness focusing mainly on the most vulnerable one and supporting them by giving them the tools to start making their own plans. It is important also through the CRA to identify the existing weaknesses and strengths in order to target and enable success factors and face barriers. CRA is expected to be the implementation tool that will track the changes in existing risks, monitor and evaluate the adaptation actions that will be implemented and as such to serve the strategic goal of Attica to be a resilient region.

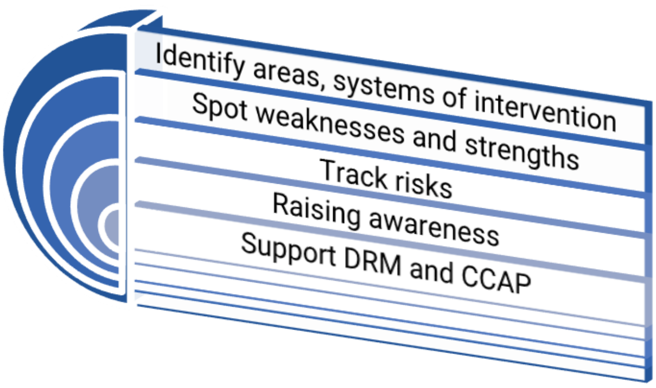


Figure 2-1Objectives of CRA

CRA require a wide range of quantitative and qualitative data that are relevant at local scales and consistent with the required scope. However, the necessary data are often difficult to access and use—e.g., climate data because of data volumes and domain-specific data formats. Data can also be complex and expensive to generate, such as exposure/vulnerability/policy datasets, and contain inherent uncertainties because of undetermined and unpredictable elements. In addition, as CRA must be periodically updated, it can be challenging to acquire the necessary data because data providers may not update datasets with the required frequency or spatio-temporal resolution.

Stakeholder participation is crucial for the risk assessment and the collective risk management. Attica Region during the execution of the CCAP has created CoPs for every sector (tourism, agriculture, health etc) involving them mainly during the assessment of the proposed adaptation measures. Taking into account the pool of these stakeholders (national and local authorities, private sector, policy makers), the difficulties in the involvement and the lessons learned a stakeholder list has been prepared. This will ensure the development of a sound communication strategy in order to manage the relationship and the development of appropriate CRA and uptake into strategic planning (Mil.1) having in mind that the inclusion of stakeholders is a dynamic procedure and as such it can be changed after the outcomes of the Risk Analysis.

Stakeholder engagement is an integral part of risk assessment and contributes to sound risk management, particularly if approached in an inclusive manner. It is important to seek out and enlist experienced and dedicated social facilitators to ensure the uptake of obtained results and recommendations into project or policy design. It is also essential to keep in mind that in many cases the capacity of the stakeholders (even Departments of the Region or Municipalities) that take part in participatory processes will vary considerably and capacity building programs may be needed to enable stakeholders to participate fully and effectively.

2.1.2 Context

According to Law 4662/2020, risk assessment in Greece is a prerequisite and a component for drafting both the Plan for Civil Protection (at the national and regional level) and the General Plans for Emergency Response and Management of Consequences. The National Risk Assessment (NRA) was developed in 2021 based on the guidelines on national disaster risk assessment developed by the United Nations Office for Disaster Risk Reduction (UNDRR) and the EU risk assessment guidelines. Region of Attica has in force plans for civil protection for hazards related to climate change and geohazards.

According to Directive 2007/60/EC Hazard maps and Flood risk maps are available in Greece for the potentially High Flood Risk Zones, as derived by the preliminary assessment. The completion of mapping these areas is particularly important, since they are investigating the possibility of flood occurrence, according to specific scenarios and feeding the Plans for Flood Risk Management.

The National Strategy for Adaptation to Climate Change (NSCA) in Greece consists the first step in the planning and implementation of the necessary adaptation measures at the national regional and local level. National Strategy sets the general goals, guiding principles and means for implementing adaptation measures. 15 important sectoral policies have been selected and for each one policy actions and measures for adaptation are mentioned. These actions and measures are not prioritized but this is the scope of the Regional Plan for Adaptation to Climate Change. In the RCPPA of Attica scenarios are included and there are projections for climate change focusing on 10 sectors that are the most vulnerable (agriculture, biodiversity and forests, fishery, water and floods, coastal zone, tourism, energy, infrastructures, health, urban environment and cultural heritage).

Although the strategies and the plans exist what is important in regional and local level is a robust tool for CRA that can help communicate the risks with policy makers, thereby supporting adaptation planning and a tool for monitoring and evaluating the adaptation measures supporting again the policy by analyzing the most vulnerable and exposed elements (infrastructure, population, buildings etc).

Over the past years, a significant increase in the number of forest fires has been observed in Attica. Although very complex, some of the main causes for this increase identified in the scientific literature are related to drought cycles possibly linked to climate change (Dimitrakopoulos, A. et.al, 2011), changes in forest and wildfire management policies, and land use planning practice. The statistics reveal an increasing number of fires after 1989 in Greece and the greatest is observed in the area of Attica among others (Kotroni, V. et.al, 2021).

Recently, a devastating flash flood, which affected Mandra (in the western Attica region) on 15 November 2017, resulted in 24 deaths and great economic losses, highlighting the consequences of urbanization, uncontrolled construction, and changes in land use. Hydrological regimes are affected by climate change. In particular, an increase in the intensity and the frequency of floods, due to human-induced climate modifications, has been reported in the literature (Galanaki et al., 2021).

Greece's major climate change impacts are expected in the form of extreme weather events, such as heat waves, forest fires, and floods, as well as prolonged droughts and rising sea levels. According to the NRA, fire risk is expected to increase for all studied climate scenarios, especially in inland locations. Representative Concentration Pathway (RCP) scenarios are not included in the NRA but might be implicitly referenced in the research studies cited in the report. Overall, there are few projections for climate change hazards included in the NRA, although specific hazards such as fires and flooding do use deterministic scenarios to evaluate risk of certain return period hazards events. The NRA reports on climate model projections that have found an expected increase in rainfall intensity in warmer climates, which in turn is directly associated with flash floods and urban floods. The NRA also cites research that highlights the relationship between increased landslide activity and increased humidity, with a potential increase in extreme rainfall events leading to more frequent landslide events. The NRA notes climate change impacts on wildfires, which are expected to increase in number and intensity in many parts of Greece. Due to the expected increase in temperatures, decrease in summer rain, and decrease in relative humidity, the number of fire events is expected to increase as well as the extent of the burnt areas. Fire hazard and drought are directly correlated, and the expected hotter and drier climate leads to an increase in the likelihood of wildfires. The literature review also identified a future increase in the intensification of heavy and extreme precipitation events in the city of Athens; the percentage of precipitation amount due to extreme precipitation for the 2051–2100 period is projected to be almost double the reference period value. Studies focusing on specific river basins or water catchments have been carried out over the past few years, providing varied conclusions.

2.1.3 Participation and risk ownership

It is increasingly recognized that effective climate risk assessments benefit from well-crafted processes of knowledge co-production involving key stakeholders. To support the co-production of actionable knowledge on climate change, a careful design and planning process is often called for to ensure that relevant perspectives are integrated and to promote shared understandings and joint ownership. Within a single community, the realities of climate change risks are quite different due to the variation in livelihoods. Livelihoods based e.g. on tourism, construction and office work, face mainly indirect risks via impacts to markets, communication networks and infrastructure (Field et al., 2012). But regional and local governments can take ownership of urban flood risks and engage themselves in infrastructure planning and community education. Risk-informed decisions, co-produced climate services and adaptation actions are interconnected and interdependent.

AtticaReAdy project taking for granted the experience gained from the stakeholder engagement during the process of Climate Change Adaptation Plan used the pool of these stakeholders (national and local authorities, private sector, policy makers) and the guidance available on CLIMAAX Framework on stakeholder engagement to prepare a stakeholder list (Mil 1) in order to ensure the development of a sound communication strategy and manage the development of appropriate CRA and uptake into strategic planning.

AtticaReAdy CoP has already been established with 4 key institutions participating in the core group so far. During Phase 2 the core group is planned to be enlarged and a workshop will be organised, aiming to inform a large majority of the 66 municipalities of Attica Region and regional and local officers that have the mandate to develop DRM and CCAPs. Dissemination of the results of AtticaReAdy through the Climate Adaptation Observatory of the Region of Attica will be conducted during Phase 2 and communication actions in order to share results with the stakeholders (policy briefs, info-packages etc). The aim is also to inform social groups and economic activities on how hazards and risks will potentially change in the short and long-term encouraging the protection of their own interests and the construction of their own defence. But the main group will be the municipalities and mainly the most vulnerable not only those that are exposed to certain hazards but also those that don’t have the local capabilities to design or update their DRM plans.

2.2 Risk Exploration

2.2.1 Screen risks (selection of main hazards)

The climate of Attica is temperate and belongs to the Mediterranean climate type. Rainfall occurs mainly from October to April, but overall, throughout the year the rainfall is very low and does not exceed 400-450mm. More rain occurs in the eastern and northern parts of the prefecture. Snowfall occurs almost every year in the surrounding mountains of Attica, more rarely in the northern suburbs of Athens and even more rarely in the city centre. In recent years, snow has made its presence felt in the city many times (2002-2004-2006-2008). The temperature even in the winter months fluctuates at high levels with the middle of January fluctuating at 9.2°C. In the summer months, temperatures reach very high levels and for a few days, a heat wave occurs with temperatures that even exceed 40°C. In the basin and in densely built-up areas, conditions prevail significantly and burden the already warm natural climate of Attica.

Attica region faces extreme forest fire events almost every year, constantly rising in frequency and severity during the last two decades. In particular, Attica has witnessed numerous fire incidents with significant consequences (Arianoutsou, et al., 2023). Among recent incidents, the fire in Mati, Attica, commencing on 23 July 2018, resulted in the tragic loss of 102 human lives and substantial property damage over an area of 1300 hectares (Efthimiou, et al., 2020).

A critical component of effective wildfire prevention policies and strategies is a long-term wildfire risk assessment, based on robust methods accounting for the spatial and temporal nature of wildfire risk. On a local scale, such wildfire risk assessment could be used for areas to be treated for wildfire risk reduction, fuel treatment practices implementation, fire towers and water tank construction. This information is extremely useful in implementing efficient preventive strategies and measures, since fire prevention is not only preferable but also a cost-effective way to manage forest fires when compared to fire fighting and suppression. Availability of information on wildfire risk assessment on a regional scale supports optimal allocation of fire-fighting personnel and the protection of critical infrastructure (Kalabokidis, 2012).

2.2.2 Workflow selection

2.2.2.1 Workflow River Flood

According to the previous step of Risk Exploration Fluvial Flood Workflow was used to identify the flood hazard analysis for the Region of Attica. To estimate the impact of climate change on flood potential, flood maps were retrieved for different climate models and future scenarios across multiple years in order to qualitatively compare the flood maps under different climate change scenarios. The workflow was applied also in the area of Kifisos River the largest river in the region that crosses the whole region from north to south with a fully developed urban area around.

2.2.2.2 Workflow Wildfire

According to the previous step of Risk Exploration Wildfire Workflow was applied using the Fire Weather Index. The FWI is a climatic indicator that intergrates daily observations of surface air temperature, rainfall, wind speed and relativy humidity, reflecting the influence of weather conditions and fuel moisture on fire behaviour. The index assigns a score ranging from 0 to 100, representing the suitability of climatic conditions for wildfire occurrence.The whole area of the region was selected (EL30). The aim is to assess the effect of climate change on the regional wildfire development risk and to define the most vulnerable areas of the region. Additionally the aim is to estimate potential changes in fire weather season length under different climate conditions.

2.2.3 Choose Scenario

The Aqueduct Flood Hazard Maps dataset was used to assess the impact of climate change on river floods. Flood hazard analysis for the Region of Attica was done for different return periods (10, 50, 100 years) including flood maps for extreme flood events (250 years return period) in the baseline climate (ca. 1980) and in the future climate (2030, 2050, 2080 for RCP 4.5 and RCP 8.5 scenarios).

Wildfire: The RCP2.6 scenario was selected from the available options, the multi-model ensemble mean was chosen for robustness and the mean-case severity was used. The length of the fire weather season was determined by summing the fire weather days, defined as days when the FWI exceeds a designated threshold. This analysis was performed for both historical and future periods to quantify projected changes. The FWI threshold of 30 was defined based on local conditions and requirements.

2.3 Risk Analysis

2.3.1 Workflow Fluvial Flood

Table 2-1 Data overview workflow Fluvial Flood

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
Pre-processed river flood maps from JRC	GDP and economic vulnerability adjustment (LUISA damage info curves)	Built infrastructure exposure	Economic damages from river flooding
Flood hazard data for different return periods	Land use maps for vulnerability assessment	Population density in flood-prone areas	Estimated financial loss assessment
Aqueduct Floods dataset for baseline scenario (1980)	Damage curves for various land-use categories	Critical infrastructure affected (roads, bridges, utilities)	Risk quantification using scenario-based flood modeling
Projected flood maps for 2030, 2050, and 2080 under RCP4.5 and RCP8.5	Regional socio-economic data	Industrial and commercial buildings in high-risk zones	Customizable risk assessment based on local economic parameters

2.3.1.1 Hazard assessment

In Phase 1 for the fluvial flood risk assessment the Europe wide dataset was used even though the dataset includes only large river basins (larger than 150km^2) and does not include flood protections. The reasons for this choice were to get familiar in this phase with the workflow and to compare the results with those from flood maps more representative for Attica available from other projects. The flood maps retrieved from JRC for the area of RoA and for the area of Kifisos River are shown in Figure 3.1. Kifisos river has a river basin of 363,7km^2 a perimeter of 144,7km and includes 34 municipalities (part or the whole) out of 66 in total of the region.

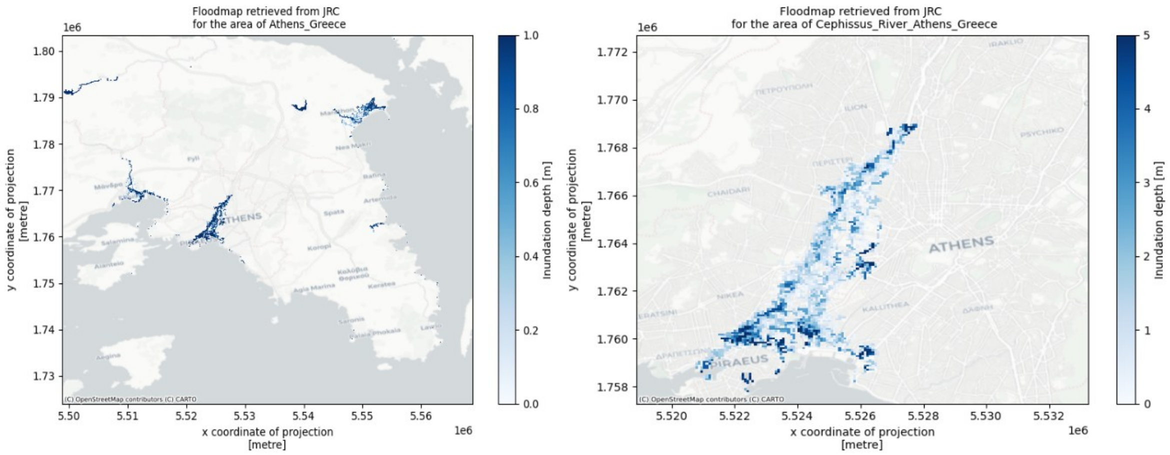


Figure 2-2 Hazard flood map for the whole area of the region (left) and the area of Kifisos River (right)

In the area of Kifisos River has been done a comparison of the flood maps for different scenarios and return periods by merging the datasets.

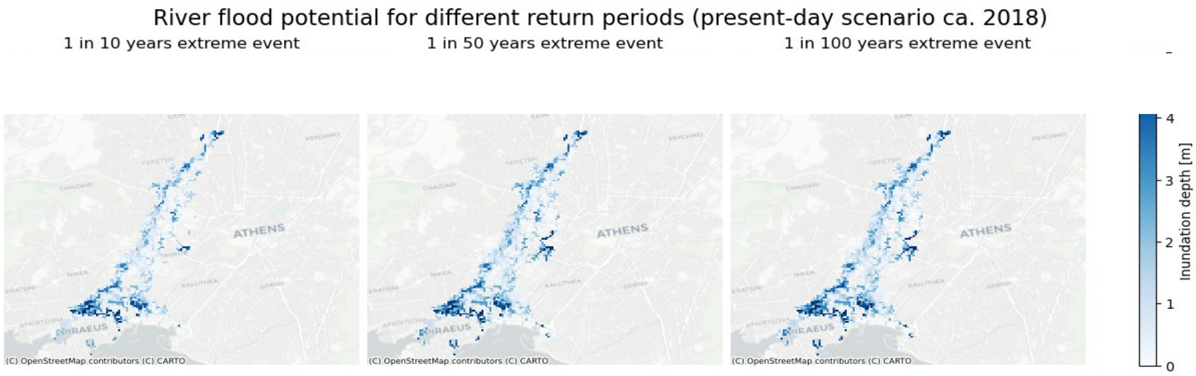


Figure 2-3 River flood potential for different return periods (present day scenario 2018) Kifisos River

Flood maps from Aqueduct Flood Hazard Maps dataset were used to assess qualitatively the change in river flood hazard under different climate scenarios. The flood map for extreme flood events in the baseline climate (2018) and in the future climates (2030, 2050, 2080) for RCP8.5 climate scenario didn't help to understand and distinguise areas with higher inundation depth than others. The result of these hazard maps was that the flood depth will increase under the climate scenario of RCP8.5 for all the given years (2030, 2050, 2080).

2.3.1.2 Risk assessment

The Risk analysis for river flooding in the Attica Region is based on the previously conducted hazard analysis for the whole area of the region and for the river basin of Kifisos River. This process includes assessment of exposure, vulnerability and potential damages to infrastructure, population and economic assets. Using the damage curves an estimation of economic losses is available by linking flood depth to expected damages per land use category.

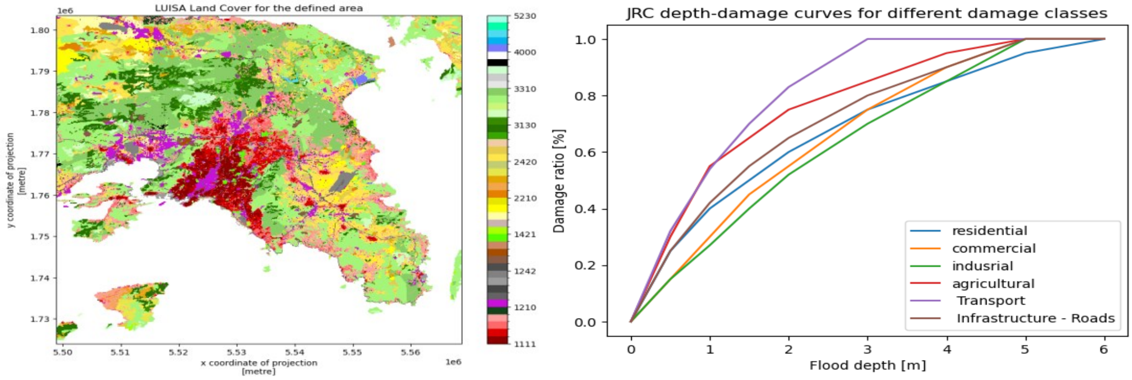


Figure 2-4 Land cover for Attica region (left) and depth-damage curves (right)

The risk calculation was done using the flood map, the land use map, the vulnerability curves per land use category and the maximum damages per land use category. In the figure below is the overview of the potential flood depth and the associated economic damages for the river basin of Kifisos.

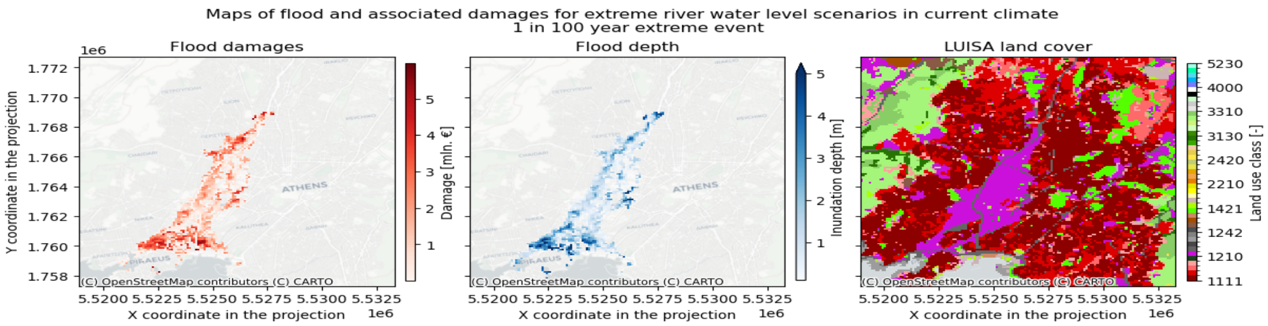


Figure 2-5 Maps of flood and associated damages for the river basin of Kifisos River

According to the results about flood depth and flood damages high inundation results in high flood damages. The projected damages due to river flooding increase under the climate change. The main land use of the river basin of Kifisos is residential so in order to obtain more accurate results it is important to use information (Phase 2) that are related with the density of the population, the age of the population and probably the type of buildings (vulnerability data) and the cost of the land, €/m^2 (exposure data) for estimating the economic losses.

2.3.2 Workflow Wildfire

Table 2-2 Data overview workflow wildfire (FWI)

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
Seasonal Fire Weather Index (FWI) from Copernicus Climate Data Store	Population in Wildland Urban Interface	Regional human settlements	Fire Danger Index (combining FWI and burnable vegetation)
Daily FWI for fire season length analysis	Protected Areas distribution	Economic assets at risk	Fire Season Length assessment

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
Filtered FWI removing non-flammable areas (ESA-CCI Land Cover)	Ecosystem Irreplaceability Index	Critical infrastructure exposure	Composite Risk Index using Pareto analysis
Burnable vegetation percentage from EFFIS	Population Density	Ecological zones at risk	Customizable risk assessment based on selected vulnerability indicators
	Ecosystem Restoration Cost Index		

2.3.2.1 Hazard assessment

The hazard assessment is based on the Fire Weather Index (FWI) which is a climatic index combining data on daily noon surface air temperature, rainfall intensity, wind speed and relative humidity accounting for the effect of fuel moisture and weather conditions on fire behavior. It consists of a 0-100 score indicating how suitable the climate conditions are for the occurrence of wildfire. Changes in seasonal FWI Intensity were analyzed using the RCP2.6 emission scenario for the period 2045 – 2054. The multi-model ensemble area was chosen for robustness and the mean case severity was used.

The results for the Average FWI over the period of 2045 -2054 and of the yearly (2051, 2054) variation in FWI intensity are shown in the figures:

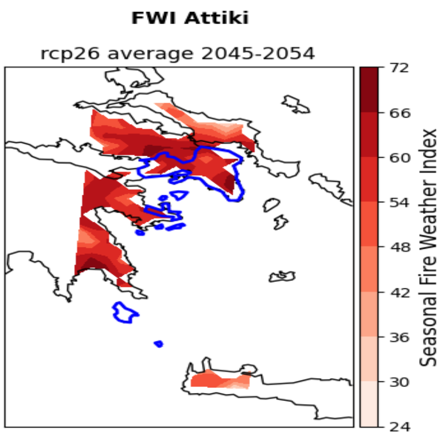


Figure 2-6 Average FWI over the period of 2045 -2054 for RCP2.6

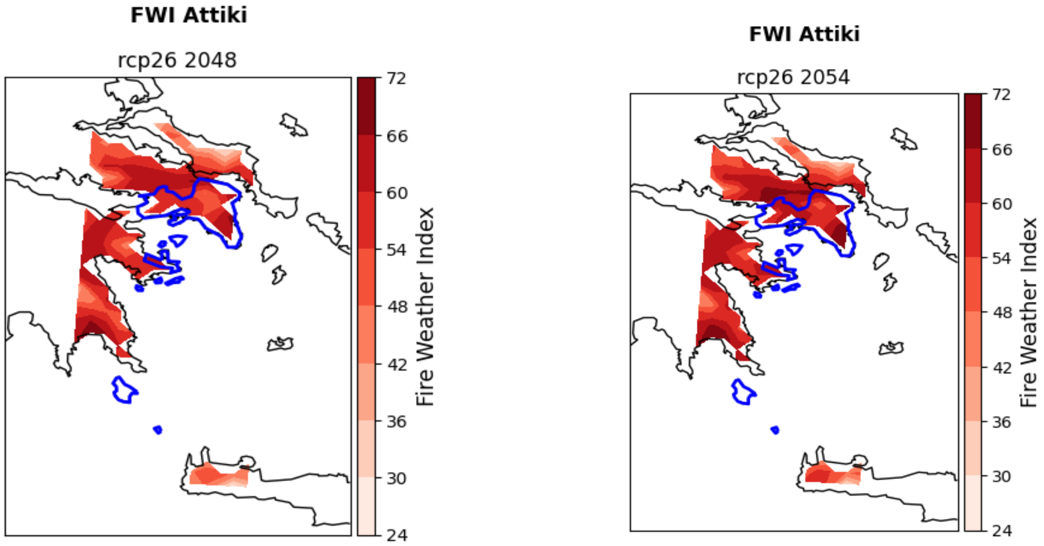


Figure 2-7 FWI intensity for the years 2048 and 2054

The FWI values are classified into fire danger categories based on EFFIS criteria. The whole region has a FWI higher than 38 and the fire danger class is Very High, with the area of South Attica above 66 (extreme to very extreme fire danger). Even though the EFFIS FWI thresholds systematically overestimate the wildfire danger and the critical values of the European system are considered too low and, therefore, not representative of the conditions in Greece (Papagiannaki, 2020) the results of the analysis indicate that FWI is giving the trend only very weakly related to wildfire occurrence, while it has a stronger correlation with fire size. Focusing on South Attica an increasing FWI trend over time can be observed indicating a warming and dry climate, leading to greater wildfire susceptibility. This conclusion is in compliance with the results of the Region's CCAP where the difference of the maximum mean temperature during the summer between the period 1981-2000 and 2031-2050 for South Attica for RCP4.5 and RCP8.5 is more than 1.5° C,

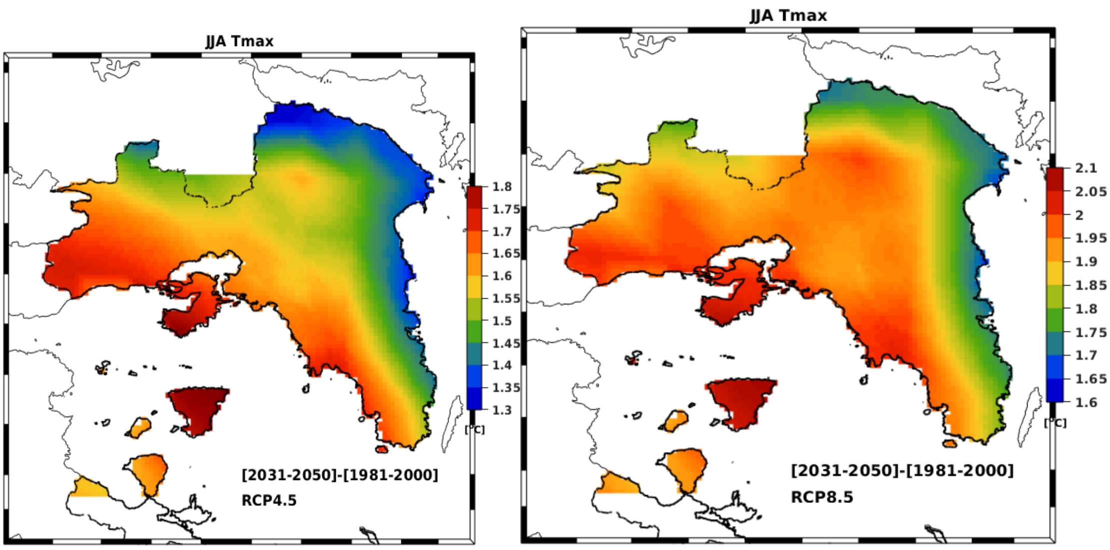


Figure 2-8 Change of the mean Tmax during summer for the period 2031-2050 for RCP4.5 and RCP8.5

For the Region of Attica is important to be aware of the magnitude of the fire weather season length extremes in order to design effective and resilient adaptation measures but also to evaluate the potential changes in fire weather season in order to proactively prepare the resources needed since a prolonged fire weather season means more human resources and an increase in the budget for prevention measures.

The length of the fire weather season is determined by summing the fire weather days, defined as days when the FWI exceeds the threshold of 30 performed for both historical and future periods. The mean scenario which represents the average fire weather season depicts the area of South Attica as the area where preventive measures must be taken.

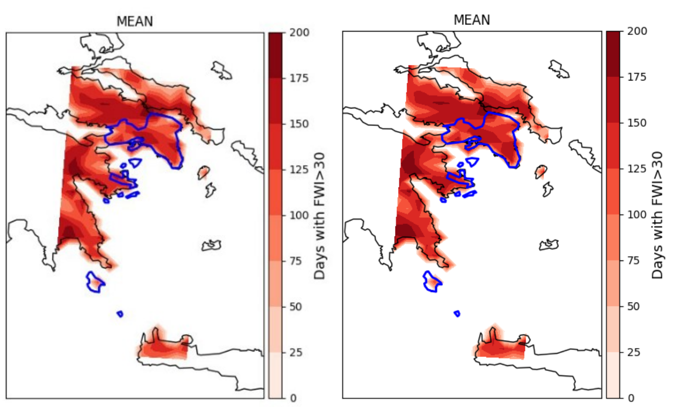


Figure 2-9 Days with FWI>30 (mean conditions) for historical data on the left and RCP8.5 mid-century on the right

According to the results during the historical period South Attica experienced 40-60 days/year exceeding FWI>30 in the best-case scenario. However, under the worst-case scenario this number increases to 120-160 days indicating an increased fire risk, In the mean scenario the number of days is in the range between 75-100. In the mid-century under the RCP8.5 emission scenario South Attica will experience 150-175 days/year with FWI>30 in the mean scenario.

2.3.2.2 Risk assessment

The Risk assessment of the FWI workflow combines data from FWI hazard with vulnerability data such as population density, burnable vegetation fraction, population living in the wildland urban interface, protected areas fraction, ecosystem restoration index.

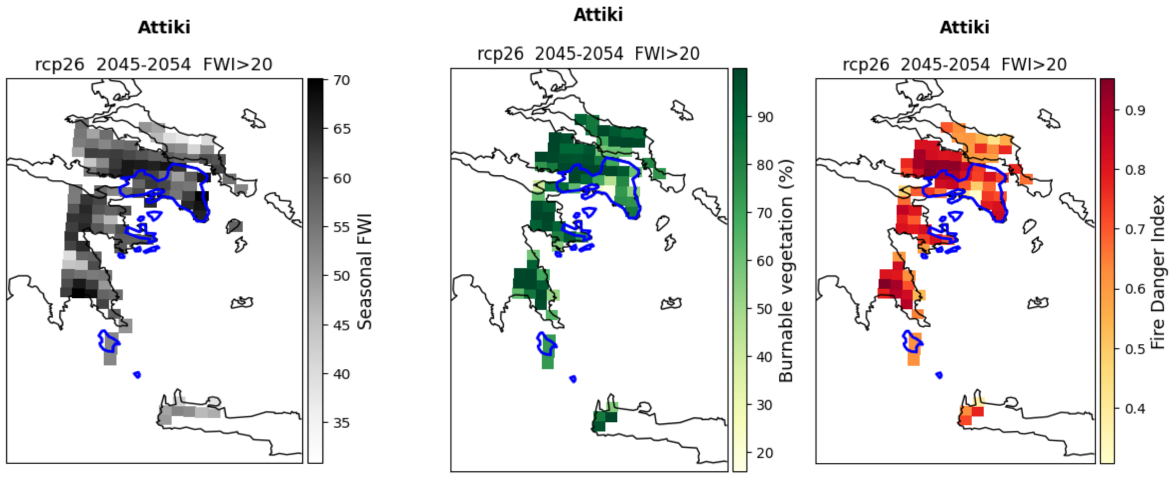


Figure 2-10 Computation of fire danger index in Attica Region: The seasonal FWI and the % burnable vegetation are combined into the fire danger index

The fire danger index together with the other vulnerability datasets were combined using Pareto analysis to identify the areas of highest risk in the region. Using all the vulnerability datasets the results shows that all the areas of the region are in high risk. So, a combination of fire danger index and the vulnerability dataset for population in wildland urban interface and the ecosystem restoration cost was done using the Pareto analysis identified the areas of highest risk in the region.

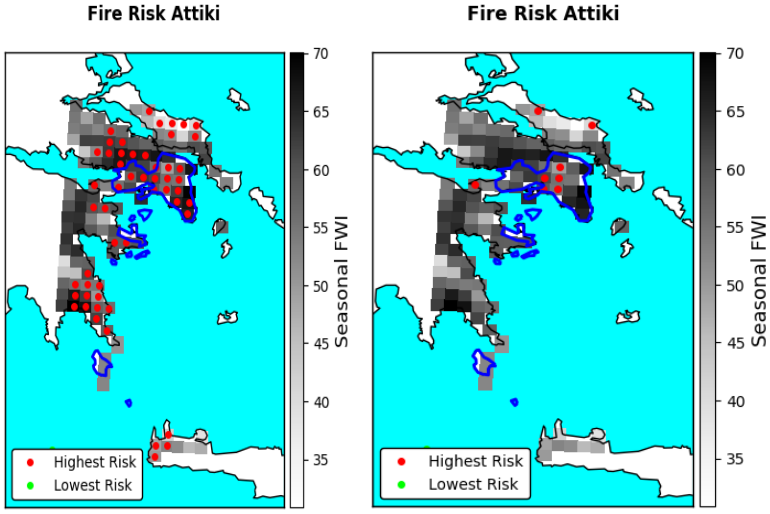


Figure 2-11 Areas with the highest risk using all the vulnerability datasets (on the left) using 2 vulnerability datasets (on the right)

2.4 Preliminary Key Risk Assessment Findings

2.4.1 Severity

Risk analysis was conducted using workflows for two hazards, wildfire and fluvial flooding and the results were presented and discussed with the CoP stakeholders in order to collect information on the perception of the risks. The CoP is consisting from the Civil Protection Departments of three municipalities belonging in the region of Attica (Municipality of Piraeus, Municipality of Vari-Voula-Vouliagmeni and Municipality of Vyronas). These three municipalities were selected to participate in the core group of the CoP because they differ a lot taking into account socioeconomic factors and geographical aspects. The Municipality of Piraeus is the biggest port of RoA and also of Greece and it is affected by river flooding of Kifisos. The other two municipalities are affected mainly by wildfire but they have a different socioeconomic status and the one is located in northern Attica and the other in the southern part of the region.

Attica region faces river flooding and extreme forest fire events almost every year, constantly rising in frequency and severity during the last two decades. The results of the CRA for fluvial flooding in the river of Kifisos are depicting that in the Municipality of Piraeus the inundation depth will be more than three meters with great impacts since Piraeus is the most densely populated area of the region with a lot of critical infrastructures. The risk of fluvial flooding can be characterized as severe because it seems that it is high in magnitude with high impacts.

For wildfire even though from the analysis the highest risk is in areas of northern Attica the FWI is high in the areas of southern prolonging the fire weather season. Taking into account the historic trends and the potential impacts, since the peri-urban forests are close to highly populated areas also wildfire risk was characterized as severe. It was also pointed out the need to analyze the risk of drought and define the period of low rainfall that will have a cascading effect to wildfire risk.

2.4.2 Urgency

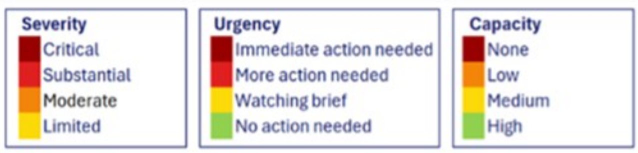
Since urgency is strongly dependent on severity and are two factors that have to be considered jointly during key risk assessment both hazards can be characterized as urgent with more actions to be addressed. Plus on top of that these hazards are projected to worsen and taking into account the fact that the DRM measures that have been implemented are not sufficient the hazards (fluvial flooding and wildfire) have to be characterized as urgent (more action needed) according to the stakeholders opinion pointing out also the impacts of previous incidents that had great impacts on the population not only in cases with fatal deaths but also in less severe incidents that had a big psychological impact on the population.

2.4.3 Capacity

Capacity depends on implemented and planned climate risk management measures that are in place to tackle the risks. According to what has already been mentioned plans and policy instruments are in place and human resources and technical skills exist but what lacks is the participatory governance and the stakeholder engagement. It is pointed out also that a key factor is the increase of public awareness especially nowadays that the civil protection seems not to be able to offer the protection that is needed to everybody. The opportunity at this point is that the public is more susceptible to these changes than ever. Last but not least is the financial aspects and the importance of mobilizing the significant investments needed to achieve the transition to climate resilience. This brings an opportunity to the regions and the municipalities to move from being applicants and recipients of public funds to being leaders of a financial planning process in order to achieve the transformations that will lead to tackle climate change risks.

Table 2.3: Key Risk Assessment Dashboard considering severity, urgency and capacity

Risk Workflow	Severity	Urgency	Capacity		Risk Priority
			Baseline CRM	Opportunities	
River Flooding					1
Wildfire					1



2.5 Preliminary Monitoring and Evaluation

At this first phase of the CRA, using CLIMAAX Framework & Toolbox, the main objective was mainly to come in touch and to know how to perform a CRA and it was accomplished taking into account the restricted available time. The results obtained promoted the proper consideration of key risks, and the identification of specific areas and systems most at risk which is the first step for the preparation of a robust and consistent DRM and CCAP. Improvement in the availability of local data on hazards, vulnerability and exposure factors combined with more competencies during Phase 2 is expected to fulfill the goal of a CRA that will minimize the potential losses and damages in human and ecological systems of the region and will support the region to manage the risks and coherently integrate them throughout policy and planning cycles.

A key message that reviled from the engagement with the stakeholders was that risk management requires a better and more holistic understanding of the interconnected, complexity and non-linear cause effect within the system's elements in order to identify appropriate response and shift from a hazard perspective to a multi-hazard and system perspective. During this procedure it is crucial to engage local governments, local communities and citizens focusing also to the most vulnerable one, giving the opportunity for different stakeholders (local governments, private sector, citizens, policy makers, public sector) to openly share their perspectives on risk information and testify their experiences.

The Key Risks (wildfire, fluvial flooding) as well as Less Urgent Risks should be monitored and observed over time not only because of interconnection between different risks but also because of the climate change a risk that now is a less urgent one can become a key risk. Taking into consideration this point at the next phase AtticaReAdy will exploit the majority of the tools that are available through CLIMAAX Toolbox for gaining the maximum profit and enriching the number of indicators that were set since the launch of the project:

- Economic damages and social impacts
- Define thresholds used in flood planning
- Predictions on where wildfires are most likely to occur
- Changes in the fire weather season length
- Change in number of days per year with FWI>30.

The new list of indicators will represent also the stakeholder's needs following the SMART scheme setting a baseline, in order to track changes by defining a periodical reassessment serving the main objective of a resilient region that nobody will be left behind.

3 Conclusions Phase 1- Climate risk assessment

Phase 1 of the AtticaReAdy project successfully established a foundational climate risk assessment (CRA) for the Attica Region, utilizing the CLIMAAX Framework and Toolbox. By focusing on fluvial floods and wildfires, the project identified critical risks, validated through stakeholder engagement, and laid the groundwork for the next steps and for actionable adaptation strategies. A clear benefit from this phase was the engagement and the collaboration of different departments of the region and also the fact that it was possible the offered tools to be used by the personnel of these departments.

The CLIMAAX workflows (e.g., Aqueduct Flood Hazard Maps, FWI analysis) proved effective in generating hazard and risk profiles. However, limitations in local data resolution and the need for multi-hazard integration were identified as critical gaps. The key findings are feeding a risk-based management approach which supports the prioritization of DRM investments with respect to the severity of the impacts that they may have to the economy, environmental, and societal assets of the region.

The key findings for the wildfire risk reviled that rising temperatures and prolonged droughts project a 175-day fire weather season by 2050 especially in Southern Attica, classified as "extreme to very extreme" danger, and also that high-risk zones overlap with wildland-urban interfaces, exacerbating threats to densely populated areas. As far as the fluvial funding key findings is concerned the Kifisos River basin faces inundation depths exceeding 3 meters under RCP8.5 by 2080, with severe economic and social impacts in urban hubs like Piraeus and that residential areas dominate the basin, amplifying vulnerability due to aging infrastructure and population density. Both hazards were classified as "severe and urgent", driven by projected worsening under climate change, insufficient adaptation measures, and cascading socio-economic impacts.

Hazard maps and risk maps are key instruments for risk management. They help raise awareness about areas at risk and help communities develop strategies for reducing these risks. Civil protection and first responders can use the maps to plan emergency responses and they can also support insurance decisions. The maps also support land-use planning, adaptation planning and urban development, particularly to avoid creating new risks.

Phase 1 underscores the urgency of addressing climate risks in Attica, a region pivotal to Greece's socio-economic fabric. By leveraging CLIMAAX's harmonized approach, the project has set a robust precedent for science-driven, stakeholder-informed resilience planning. Future phases must prioritize localized data, multi-hazard synergy, and proactive governance to safeguard Attica's communities, ecosystems, and economic vitality against escalating climate threats. This deliverable not only aligns with region's resilience goals but also positions Attica in a better situation as far as regional risk assessment is concerned, demonstrating the transformative potential of integrating technical tools with collaborative governance.

The experience gained by the interaction with the CoP is expected to benefit next phases helping to raise awareness to more municipalities of the RoA focusing mainly on the most vulnerable one and supporting them by giving them the tools to start making their own plans. Through the CRA with the CLIMAAX Toolbox and Framework it was important that the existing weaknesses and strengths were identified in order to target and enable success factors and face barriers for the future, stepping and integrating with existing schema, policies and plans.

4 Progress evaluation and contribution to future phases

The results obtained during phase 1 promoted the proper consideration of key risks, and the identification of specific areas and systems most at risk which is the first step for the preparation of a robust and consistent DRM and CCAP. The use of the tools offered by CLIMAAX was not complicated and served the possibility to extract indicators for the evaluation. During this phase it was possible to find out the capabilities of the offered tools, to set the basis to perform calculations on demand and start building the Community of Practice involving different stakeholders.

Future CRA effort will focus in improving the precision of flood and wild fire risk analysis through the integration of local, high-resolution data. This involves refining the workflows with detailed local datasets. Tailoring the analysis for RoA's specific conditions (environmental, social, economic, geographic etc) will lead in a more accurate and context specific understanding of risks, which is crucial for policy, decision making and planning. The CLIMAAX methodology and Toolbox is planned to be expanded to encompass also other hazards such as heatwaves, droughts and coastal flooding during phase 2. As the familiarization with the tools and the expertise is growing, applying the workflows to additional hazards is expected to become seamless. In this case a wider assessment of climate risks will contribute to a more robust and comprehensive DRM and CCA planning. Future CRA effort will focus also in the occurrence and interaction of multiple climate related hazards (multi hazard), which can result in more complex and severe impacts.

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
At least 2 workflows successfully applied during Phase 1	1. River Flood Workflow 2. Wildfire Workflow successfully applied
At least 2 workflows successfully applied during Phase 2	Phase 2 as planned
CoP with at least 5 key institutions/authorities/associations participating in the core group and a list of stakeholders to be updated	CoP with 4 key institutions/authorities/associations participating in the core group and a list of stakeholders partially updated
Workshop targeted to administration, policy makers	Phase 2 as planned
Info package (150 copies)	Phase 3 as planned
Note for policy makers (100 copies)	Phase 3 as planned
3 Articles in the website of the region and the Climate Adaptation Observatory of Attica (1 to announce the project start, targets and potentialities; 1 with the first results; 1	1 Article in the website of the region to announce the project start, targets and potentialities.

Key performance indicators	*Progress*
with the final results and workshop attendance)	
2 Newsletters informing the 66 municipalities of the region about the results of the project	Phase 2 and 3 as planned

Table 4-2 Overview milestones

Milestones	*Progress*
Mil 1: Report on scoping	Achieved by the end of 2024
Mil 2: Stakeholder meeting	Phase 2 as planned
Mil 3: Attend the CLIMAAX workshop mid 2025	Phase 2 as planned
Mil 4: Production of policy brief and info package	Phase 3 as planned
Mil 5: Workshop	Phase 3 as planned
Mil 6: CLIMAAX Workshop in Brussels	Phase 3 as planned

5 Supporting documentation

- Main Report (PDF)
- Outputs report (PDF)
- Communication Outputs (Official site of RoA)
- Milestone 1 (PDF)

6 References

Arianoutsou, M., Zerefos, C., Kalabokidis, K., Poupkou, A., Aravanopoulos, F., Eds.; Resilience of the Greek Forest Ecosystems to Climate Change; Committee for the Resilience of the Greek Forest Ecosystems to Climate Change (EADO); Academy of Athens: Athens, Greece, 2023; 547p, ISBN 978-960-404-413-9.

Dimitrakopoulos, A., Vlahou, M., Anagnostopoulou, C. and Mitsopoulos, I. 2011. Impact of drought on wildland fires in Greece; Implications of climatic change? Climate Change 109:331–347.

Efthimiou, N.; Psomiadis, E.; Panagos, P. Fire severity and soil erosion susceptibility mapping using multi-temporal Earth Observation data: The case of Mati fatal wildfire in Eastern Attica, Greece. Catena 2020, 187, 104320.

Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G., Allen, S.K., Tignor, M., Midgley, P.M. (Eds.), 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Galanaki, E., Lagouvardos, K., Kotroni, V., Giannaros, T., and Giannaros, C.: Implementation of WRF-Hydro at two drainage basins in the region of Attica, Greece, for operational flood forecasting, Nat. Hazards Earth Syst. Sci., 21, 1983–2000, https://doi.org/10.5194/nhess-21-1983-2021, 2021

Kalabokidis, K. Decision support system for forest fire protection in the Euro-Mediterranean region. European Journal of Forest Research, (2012) vol. 131, pp. 597-608.

Kotroni, V.; Giannaros, T., Papavasileiou, G.; Lagouvardos, K., Dafis, S. 2021. Future Changes in Severe and Extreme Weather Due to Climate Change: A Literature Review focusing on Greece. METEO, National Observatory of Athens

Papagiannaki, K.; Giannaros, T.; Lykoudis, S.; Kotroni, V.; Lagouvardos, K. Weather-related thresholds for wildfire danger in a Mediterranean region: The case of Greece. Agric. For. Meteorol. 2020, 291, 108076.