Deliverable Phase 1 – Climate risk assessment

CLIMAAX-4-BA

Portugal, Baixo Alentejo

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Abbreviations and acronyms

Abbreviation / acronym	Description
ACOS	Associação de Criadores de Ovinos do Sul (Southern Sheep Breeders Association)
AABA	Associação de Agricultores do Baixo Alentejo (Farmers Association of Baixo Alentejo)
Nerbe / Aebal	Núcleo Empresarial da Região de Beja / Associação Empresarial do Baixo Alentejo e Litoral (Business Association of the Beja Region / Business Association of Baixo Alentejo and Coastal Region)
CEBAL	Centro de Biotecnologia Agrícola e Agroalimentar do Alentejo (Alentejo Agricultural and Agro-Food Biotechnology Centre)
DRCNF	Direção Regional de Conservação da Natureza e Florestas (Regional Directorate for Nature Conservation and Forests – Alentejo Division of ICNF)
ICNF	Instituto da Conservação da Natureza e das Florestas (Institute for Nature Conservation and Forests)
ANEPC	Autoridade Nacional de Emergência e Proteção Civil (National Authority for Emergency and Civil Protection)
EBM	Empresa de Base Municipal – likely a local environmental or municipal services company (clarification may be needed)
EDIA	Empresa de Desenvolvimento e Infraestruturas do Alqueva (Alqueva Development and Infrastructure Company)
PIAACBA	Plano Intermunicipal de Adaptação às Alterações Climáticas do Baixo Alentejo (Baixo Alentejo Intermunicipal Climate Change Adaptation)
PARs	Planos de Adaptação Municipal (Municipal Adaptation Plans)
RCP	Representative Concetration Pathway
LST	Land Surface Temperature
AWC	Available Water Capacity

Executive summary

Baixo Alentejo, a predominantly rural region in southern Portugal, is increasingly vulnerable to climate change impacts. Its Mediterranean climate—marked by hot, dry summers and irregular rainfall—makes it particularly susceptible to agricultural droughts, wildfires, and heatwaves. These hazards are projected to intensify in the coming decades due to rising temperatures and changing precipitation patterns. At the same time, socio-economic factors such as rural depopulation, ageing demographics, and economic dependence on agriculture and forestry further exacerbate regional vulnerability.

In response, the Intermunicipal Community of Baixo Alentejo (CIMBAL), in partnership with greenmetrics.ai, conducted a Phase 1 Climate Risk Assessment (CRA) under the CLIMAAX framework. The assessment aims to identify key climate risks, evaluate hazard exposure and vulnerability, and establish a foundation for evidence-based adaptation planning. The approach aligns with national and EU adaptation strategies and supports the development of harmonized assessments across European regions.

Three climate hazards were assessed using dedicated workflows: agricultural droughts, wildfires, and heatwaves. The drought workflow used MAPSpam 2010 crop data and ECLIPS 2.0 climate projections (2026–2050) to map water stress across the region. While it revealed widespread precipitation deficits, its ability to quantify local economic impacts was limited by the absence of key regional crops such as olives and vineyards. The wildfire workflow applied land cover data (CORINE 2018) and ECLIPS 2.0 projections in a machine learning model. However, due to limited historical fire events in the region, model performance was constrained, prompting the development of a broader national model. The heatwave workflow, combining climate projections with demographic data from WorldPop, identified areas of high risk—especially in Beja, Moura, and Serpa—driven by concentrations of elderly populations and urban heat island effects.

An initial stakeholder workshop held in January 2024 provided critical input for hazard validation and data prioritization. Though engagement and model calibration remain at early stages, this first phase offers a clear, regionally grounded picture of climate risk and lays the groundwork for targeted improvements.

The outcomes of Phase 1 highlight the need for further data integration, improved model alignment with local conditions, and deeper stakeholder collaboration. These next steps will guide Phase 2 and support the development of robust, locally adapted climate strategies in Baixo Alentejo, contributing to the overarching goals of the CLIMAAX initiative.

1 Introduction (3 pages)

1.1 Background

The Baixo Alentejo is a sub-region of the Alentejo Region, covering a vast area of approximately 8,544.6 km², located in the southeastern quadrant of mainland Portugal, within the Alentejo region. Administratively, the sub-region falls within the district of Beja and comprises 13 municipalities, all characterized by low population density: Aljustrel, Almodôvar, Barrancos, Beja, Castro Verde, Cuba, Ferreira do Alentejo, Mértola, Moura, Ourique, Serpa, and Vidigueira. These municipalities form part of the Intermunicipal Community of Baixo Alentejo – CIMBAL.

Climatically, Baixo Alentejo is classified as a Mediterranean climate region, characterized by a high annual average temperature. The interior experiences significant temperature variations, with days exceeding 25ºC for more than a third of the year. Annual rainfall is unevenly distributed, with most precipitation occurring in autumn and winter, while there is a marked shortage of rainfall in summer. As such, the region is known for its hot, dry summers and mild winters, making it particularly vulnerable to climatic extremes.

Recognized for its strong cultural, natural, and scenic identity, the Baixo Alentejo territory is dominated by vast plains and extensive agricultural and forestry production areas. This land use is encouraged not only by the favorable climate and geographical conditions but also by the Alqueva hydro-agricultural infrastructure. The rural characteristics of the region are inseparable from its identity. Therefore, the region is predominantly rural, with low population density and a heavy reliance on agricultural, livestock, and forestry economic activities.

One of the primary sources of income in Baixo Alentejo is closely associated with seasonal economic activities, such as agriculture, especially in the more rural areas far from the main municipal centers. These incomes are often unstable due to the climatic changes that have increasingly affected the region.

The Guadiana River, one of Baixo Alentejo's most important natural resources, is an international river in the Iberian Peninsula that originates in Spain. Upon reaching Portugal in the Alentejo, it runs along the border. Its landscapes, of significant historical and natural value, bear witness to human action over time, which has transformed the original natural cover into a variety of ecosystems adapted to the region's dryness and aridity.

This sub-region is deeply marked not only by its cultural heritage but also by its natural heritage, including examples such as the Special Protection Areas (ZPE) of Moura, Barrancos, and Guadiana, as well as the Guadiana Valley Natural Park.

In recent decades, Baixo Alentejo has experienced an increase in climate-related phenomena, particularly droughts, heatwaves, and wildfires. These events have had substantial impacts on water availability, agricultural yields, biodiversity, and the well-being of local communities. Climate projections for southern Portugal suggest that these risks are likely to intensify, with higher temperatures, reduced annual precipitation, and longer dry seasons. These evolving conditions present serious challenges to sustainable land and water management, underscoring the need for structured and regionally adapted climate risk assessments.

1.2 Main objectives of the project

Considering the above, the primary objective of this project is to conduct a climate risk assessment (CRA) for the Baixo Alentejo region, in accordance with the methodological guidelines provided by the CLIMAAX Manual. To perform a proper climate risk assessment (CRA), it is necessary to identify, evaluate, and contextualize the main regional climate risks and their impacts on ecosystems, infrastructure, economic sectors, and populations.

More specifically, the project aims to:

- Characterize the evolution and severity of heatwaves, agricultural droughts and wildfires under current and future climate scenarios;
- Map the most vulnerable areas and socio-economic groups in the region;
- Engage regional stakeholders in the co-development of knowledge and solutions;
- Inform municipal and intermunicipal planning processes with evidence-based risk information;
- Build institutional capacity for the integration of climate adaptation strategies.

The use of the CLIMAAX Handbook facilitates a harmonized and transparent approach to risk assessment, enhancing the comparability of findings across European regions and ensuring methodological rigor.

1.3 Project team

In order to carry out the planned activities, namely the climate risk assessment coordinated by the Baixo Alentejo Intermunicipal Community (CIMBAL)—which boasts an extensive multidisciplinary team comprising experts in environmental science, management, law, finance, and more, with significant experience in managing both national and international projects—it was decided to collaborate with greenmetrics.ai to ensure the achievement of the proposed objectives. Thus, CIMBAL will contribute its experience in institutional leadership and regional coordination, while greenmetrics.ai will provide specialized technical expertise in climatic data analysis and risk modelling, supporting the future integration of climate policy and innovation strategy.

This promising collaboration between CIMBAL and greenmetrics.ai will ensure that the assessment conducted is technically robust and aligned with local governance structures and development priorities.

1.4 Outline of the document's structure

This deliverable is organized into six main sections:

Section 1- Introduction

Provides a short summary of the region's background, main goals for the implementation of the CLIMAAX framework and project team.

Section 2 – Climate Risk Assessment - Phase 1

Provides a detailed analysis of climate risks affecting Beira Baixa, including hazard screening, scenario selection and risk analysis methodologies.

Section 3 – Key Findings

Summarizes the preliminary results of the assessment, including identified risks, vulnerabilities, and potential issues requiring future adaptation strategies.

Section 4 – Monitoring and Evaluation

Discusses the mechanisms for tracking progress, refining risk assessments, and integrating stakeholder feedback.

Section 5 – Conclusions

Presents the key conclusions from the preliminary climate risk assessment, reflecting on the main results obtained with this methodology and its limitations.

Section 6 – Supporting Documentation

Includes references, datasets, and supplementary materials used in the assessment.

2 Climate risk assessment – phase 1

2.1 Scoping

2.1.1 Objectives

The objective of the climate risk assessment (CRA) for Baixo Alentejo is to provide a foundational understanding of the region's exposure and vulnerability to climate-related hazards, specifically heatwaves, droughts and wildfires . The expected outcome of Phase 1 is the identification of priority risks, the evaluation of current and future hazard patterns, and the preliminary engagement of key stakeholders to inform adaptive planning strategies.

The CRA is intended to contribute directly to regional policy and decision-making by supporting the development of climate adaptation strategies in line with national guidelines and EU directives, as well as by aiding in the identification and development of measures to mitigate climate change, thereby enabling efforts in prevention as well as adaptation. The findings of this phase will guide the integration of climate risk into land-use planning, civil protection measures, and sector-specific adaptation actions.

In this phase, the outcome of the climate risk assessment is subject to certain limitations, primarily regarding the availability and resolution of region-specific data, the representativeness of existing crop models in the CLIMAAX workflow, and the preliminary nature of stakeholder engagement at this stage. Despite these constraints, this CRA is intended to serve as a robust entry point for iterative risk analysis and adaptation planning in future phases.

2.1.2 Context

The Baixo Alentejo region is highly sensitive to climate variability, with a historical record of intense heatwaves, severe droughts, and, consequently, wildfires. Its Mediterranean climate results in long, dry summers and rising temperatures, which have been intensifying and worsening in recent years, thereby exacerbating water scarcity and fire risk.

As a result of the increased intensity and severity of recent climatic events, there has been a noticeable decline in agricultural productivity, an overburdening of water resources that has both triggered and aggravated the region's ongoing desertification. Simultaneously, wildfire activity has intensified, particularly in rural and forest-adjacent areas, in the southern part of the Baixo Alentejo territory, where accessibility challenges hinder effective fire response.

In order to address these issues and promote adaptation to climate change, the Intermunicipal Community of Baixo Alentejo (CIMBAL), which integrates 13 municipalities (Aljustrel, Almodôvar, Barrancos, Beja, Castro Verde, Cuba, Ferreira do Alentejo, Mértola, Moura, Ourique, Serpa, and Vidigueira) developed, in 2018, a fundamental strategic instrument for the region the Baixo Alentejo Intermunicipal Plan for Climate Change Adaptation (PIAACBA). This plan lists a series of priority actions designed to better prepare the region for the climate changes it faces. Following CIMBAL's example, some of the municipalities in the region have developed their own Climate Change Adaptation Plans, addressing local vulnerabilities in greater detail. More recently, some municipalities have also prepared their Municipal Climate Action Plans.

All these efforts are aligned with national policies across sectors such as agriculture, forestry, water, and civil protection. However, despite the progress made, gaps remain in local coordination, technical capacity, and data integration persist, significantly limiting the effective implementation and development of the identified adaptation actions.

Given this reality, it is possible to identify the economic sectors most affected, and consequently the most critical, by climate change such as agriculture, forestry, rural development, and water supply. The large and extensive agroforestry areas in the region and reliance on rainfed cultivation, significantly increase vulnerability to drought and fire. Structural issues such as rural depopulation, ageing infrastructure, and economic dependence on climate-sensitive sectors further increase the impact of climate change on the region.

2.1.3 Participation and risk ownership

Stakeholder participation is a critical component of the climate risk assessment for Baixo Alentejo, ensuring that risk ownership is distributed across key entities responsible for land management, emergency response, environmental conservation, and public health.

To establish an inclusive and effective engagement process, a diverse set of stakeholders was identified and invited to participate in the project. This initial list includes representatives from governmental agencies, municipalities, research institutions, forestry and agricultural associations, civil protection organizations, and community-based groups. Recognizing that climate adaptation requires ongoing collaboration, this stakeholder network is expected to expand as the project progresses.

Stakeholder engagement began with a regional workshop held on 27 January 2024. This event was the first structured interaction with stakeholders and aimed to gather local insights on climate-related vulnerabilities and risk perception, with a specific focus on heatwaves, agricultural drought and wildfires.

This workshop provided a platform for participants to contribute insights, validate preliminary findings, and highlight critical data gaps. Additionally, it offered an opportunity to align analytical efforts for Phase 2 of the project, ensuring that stakeholder-provided data and objectives are effectively integrated into the next stages of climate risk modeling and decision-support frameworks.

Table 2-1 summarizes the stakeholders who participated in this initial workshop:

Table 2-1 Mapped Stakeholders

Type / Sector	*Stakeholders*
Municipalities	Aljustrel, Almodôvar, Alvito, Barrancos, Beja, Castro Verde, Cuba, Ferreira do Alentejo, Mértola, Moura, Ourique, Serpa, Vidigueira
Agriculture and Livestock Associations	ACOS / AABA
Business and Economic Development	Nerbe / Aebal
Agricultural and Biotech Research	CEBAL
Forestry and Conservation Authorities	DRCNF, ICNF

Type / Sector	*Stakeholders*
Civil Protection	ANEPC
Environment and Energy Management	EBM
Water and Irrigation Infrastructure	EDIA

This group represents a wide range of governance levels, technical and scientific expertise, and sectoral interests including agriculture, environment, forestry, and emergency management. Their early contributions were instrumental in validating the relevance of the selected risks and initiating a coordinated approach to data gathering.

Following the workshop, a process of data collection was launched, involving the stakeholders in the provision of local information, datasets, and institutional knowledge relevant to heatwaves, drought risks and wildfire. This participatory data collection effort is key to informing the CRA and tailoring it to the regional context.

Future activities will include follow-up workshops, dissemination of technical findings, and targeted engagement based on sector-specific priorities. This inclusive process aims to strengthen regional climate adaptation efforts through co-production of knowledge and sustained dialogue.

2.2 Risk Exploration

2.2.1 Screen risks (selection of main hazards)

The initial screening of climate risks in Baixo Alentejo identified three priority hazards: heatwaves, droughts, and wildfires. These were selected based on historical evidence, stakeholder feedback, and alignment with existing strategic plans, including the PIAACBA and municipal-level PARs.

Heatwaves are an emerging climate hazard in the region, both as a compounding factor in wildfire risk and as a direct threat to public health, labor productivity, and infrastructure. Increasing frequency, intensity, and duration of heatwaves in recent decades have been observed, with implications for vulnerable populations, especially the elderly isolated people and those working in outdoor sectors such as agriculture and construction.

Droughts are a recurrent and increasingly severe phenomenon in the region, with major implications for agriculture, water availability, ecosystem and biodiversity. Projected reductions in precipitation, coupled with higher evapotranspiration rates, threaten both rainfed and irrigated farming systems, as well as surface and groundwater reserves.

Wildfires have growingly become a climate risk threatening the Alentejo region, particularly during the dry summer season. Contributing factors include high fuel loads, extreme heat, land abandonment, and limited accessibility for firefighting. Climate change is expected to intensify these conditions by increasing the frequency of heatwaves and prolonging drought periods.

All three risks were confirmed as relevant through the stakeholder workshop held in January 2024. Participants reinforced the urgency of addressing these hazards and highlighted their interrelated impacts on land use, economic stability, and social vulnerability.

In addition to the three selected risks, several stakeholders working in climate change policy and implementation also expressed concern over the increasing frequency and severity of extreme weather phenomena, particularly strong wind events and episodes of intense precipitation. Although not chosen for detailed assessment in Phase 1, these hazards were recognized as emerging threats that warrant further monitoring and may be incorporated into the CRA's scope in future project phases.

Preliminary data analysis corroborated these concerns. For heatwaves, observed temperature records and projected increases in extreme heat days point to escalating stress on both human health and ecological systems. For droughts, soil moisture indices, precipitation anomalies, and agricultural yield projections indicate persistent and intensifying stress on productive land. For wildfires, historical burn area records and predictive modelling using RCP scenarios suggest an upward trend in fire risk across most of the territory.

While these three risks are the primary focus of Phase 1, other climate hazards—such as floods and storms—may be explored in future phases, particularly if new data or stakeholder input supports their relevance.

2.2.2 Workflow selection

2.2.2.1 Workflow #1- Agricultural Drought

Agricultural drought was addressed through a workflow combining precipitation deficits and crop yield impacts under future climate scenarios. This was selected to reflect the region's strong dependence on agriculture and increasing exposure to water scarcity. Although the currently modelled crops do not fully match Baixo Alentejo's dominant agricultural systems, the workflow helped highlight the spatial distribution of hazard exposure and supported stakeholder discussions on crop-specific vulnerabilities. Future phases will incorporate regionally relevant crops through the integration of local datasets.

2.2.2.2 Workflow #3 – Heatwaves

The heatwave workflow was selected to assess the impacts of increasing temperature extremes on human health, productivity, and infrastructure. This workflow enabled the analysis of both short- and long-term exposure under RCP 4.5 and RCP 8.5 scenarios, making it well-suited for understanding both immediate and future risks. Heatwaves were identified as a compounding hazard that amplifies both wildfire and drought risks, justifying their inclusion despite limited historical treatment in prior regional assessments.

2.2.2.3 Workflow #2 - Wildfires

The wildfire workflow was selected due to the increasing incidence of fire-prone conditions in Baixo Alentejo and stakeholder concern over fuel accumulation and fire response capacity. The machine learning-based approach offered by the CLIMAAX framework was applied using regional climate projections and land cover data. While the regional model yielded limited predictive performance due to an imbalanced training dataset, its structure provided a valuable basis for future model refinement. This workflow will continue to evolve through the development of a national model calibrated for Portuguese territory.

2.2.3 Choose Scenario

For this Phase 1 assessment, the climate risk analysis focused primarily on the near-term timeframe (2021–2040) under the RCP 4.5 emissions scenario. This decision reflects both the availability of model outputs and the desire to inform short- to medium-term planning horizons aligned with regional policy and infrastructure cycles.

Due to data limitations—particularly in the wildfire workflow—longer-term scenarios (e.g., 2041–2080) were not prioritized, as preliminary model outputs showed reduced performance and limited spatial variability. The selected near-term scenario under RCP 4.5 also better corresponds with current stakeholder priorities and ongoing climate adaptation plans. For wildfires, this corresponds to the 2021-2040 period and, for agricultural drought, the 2026-2050 period.

In contrast, the heatwave workflow was applied for both near- and longer-term periods, using RCP 4.5 and RCP 8.5 pathways. This broader temporal scope was chosen to reflect the increasing urgency and long-term health implications of extreme heat events across Baixo Alentejo.

2.3 Risk Analysis

2.3.1.1 Hazard assessment - Agricultural Drought

The hazard component of agricultural drought was assessed using multiple sources of environmental and agronomic data. A visualization of the historical values of AWC across the NUTS2 region of Alentejo (Figure 2-1) was used to establish baseline soil water retention potential. This spatial dataset highlights subregional heterogeneity in soil capacity to hold water and support crops during dry periods. Areas with lower AWC are especially susceptible to rapid drought onset under dry conditions, increasing the stress on rainfed agriculture.

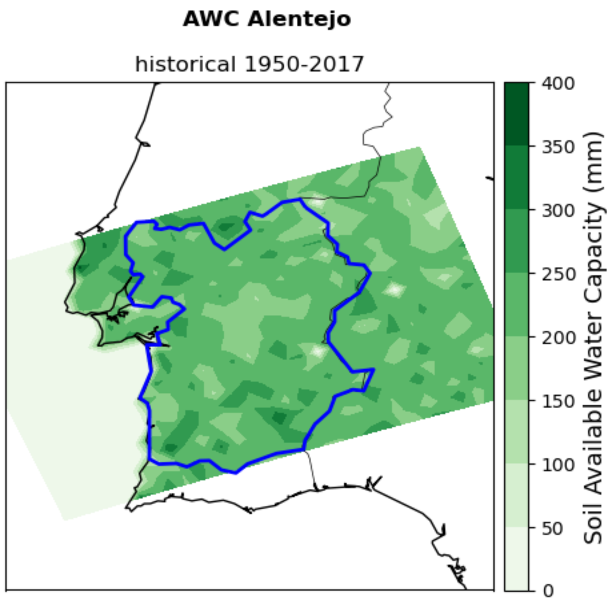

Figure 2-1 Historical Available Water Capacity for the NUTS2 region of Alentejo

To complement this, two additional indicators were examined. The first is precipitation intensity throughout the growing season (Figure 2-2), which reveals seasonal water availability trends and the risk of prolonged dry spells. The second is a standardized evapotranspiration index based on historic and projected climate data (Figure 2-2), indicating crop water demand stress over time.

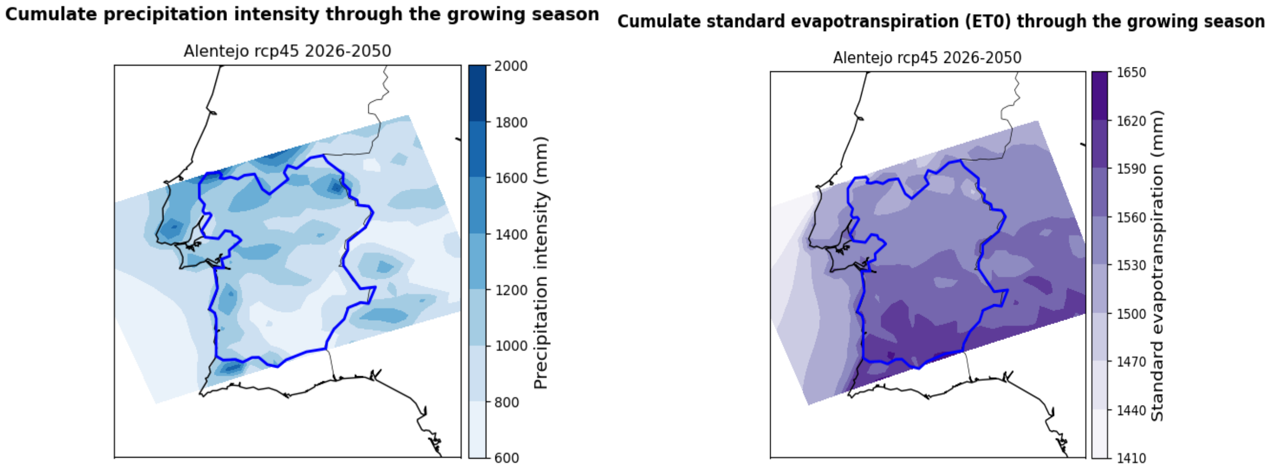

Figure 2-2 Projected cumulate precipitation intensity and standard evapotranspiration through the growing seaso

Yield loss indicators based on precipitation anomalies were also analyzed to approximate the agricultural impact of droughts. However, a key limitation emerged: the crop types covered in the CLIMAAX workflow database do not include some of the most economically relevant crops in Baixo Alentejo, namely olives, vineyards, and certain dryland cereals (and some of these that are included don't have significant production yields on 2010's MAPSpam model). Consequently, while available outputs help infer general trends in drought-related yield reductions, they are insufficient for direct interpretation at the local level.

The scenario selected for this assessment corresponds to a short-term projection (2026–2050) under an intermediate emissions pathway (e.g., RCP-4.5). This scenario was prioritized based on stakeholder interest in medium-term planning horizons and climate adaptation policy timelines. Other timeframes, such as mid-century and end-century scenarios, were not pursued in this phase due to the low spatial production density values for Alentejo observed in the MAPSpam database. These low values limit the reliability and relevance of agricultural output indicators across time.

Overall, the available hazard data provides useful insights into the biophysical conditions contributing to agricultural drought in Baixo Alentejo. However, further refinement is necessary to align drought modelling with regional crop typologies and production systems. This will be addressed in the next project phase by integrating more region-specific agronomic datasets and crop-specific models.

Still, Figures 2-3 through 2-8 represent the yield loss associated with the projected precipitation deficit for some of the available crops in the agricultural drought CLIMAAX workflow as of right now, in the period of 2026-2050, considering the RCP 4.5 emissions scenarios. This selection serves as an example as all of the available crops got similar results in this Phase 1 of the project.

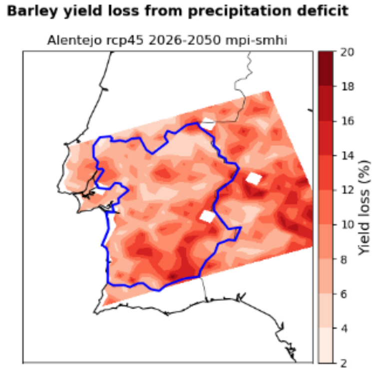

Figure 2-3 Projected yield loss for Barley due to the deficit in precipitation, in % of current value

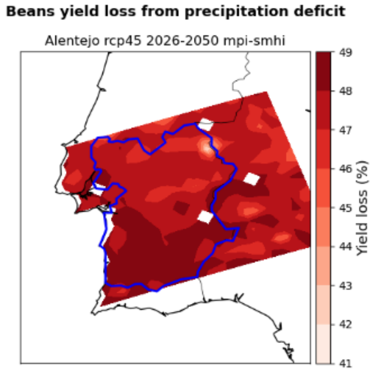

Figure 2-4 Projected yield loss for Beans due to the deficit in precipitation, in % of current value

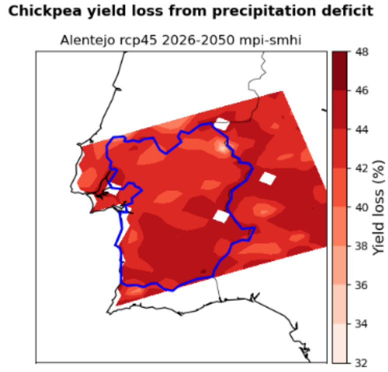

Figure 2-5 Projected yield loss for Chickpea due to the deficit in precipitation, in % of current value

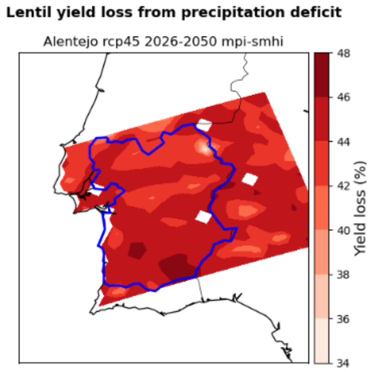

Figure 2-6 Projected yield loss for Lentil due to the deficit in precipitation, in % of current value

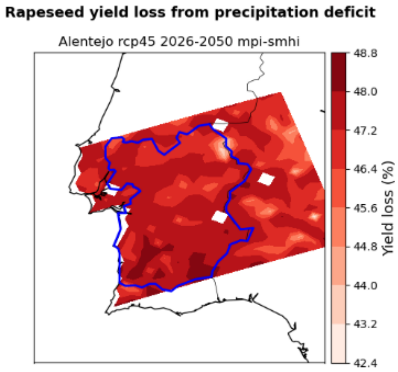

Figure 2-7 Projected yield loss for Rapeseed due to the deficit in precipitation, in % of current value

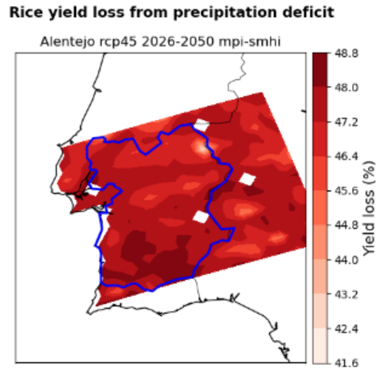

Figure 2-8 Projected yield loss for Rice due to the deficit in precipitation, in % of current value

2.3.1.2 Risk assessment - Agricultural Drought

To assess the potential economic impacts of agricultural drought in Baixo Alentejo, projected production losses in euros were calculated for the crop types available in the CLIMAAX workflows. The resulting figures underscore a significant limitation: total estimated losses are extremely low across all included crops, with many municipalities showing negligible or zero projected impacts.

This outcome does not imply low vulnerability to drought in the region; rather, it reflects a misalignment between the crop types modelled within the CLIMAAX framework and the actual agricultural profile of Baixo Alentejo. The region's dominant crops—such as olives, vineyards, and traditional dry-farmed cereals—are not represented in the workflow's baseline yield-loss models. As a result, the calculated financial risk does not accurately capture the real magnitude of climate impacts on local production systems.

In Figures 2-9 through 2-14, the total projected losses for each available CLIMAAX crop are presented for Baixo Alentejo. Values across all timeframes remain low, reinforcing the rationale for prioritizing the short-term scenario while excluding other periods from detailed analysis. The

MAPSpam production density data for Alentejo corroborates this choice, as it identifies minimal representation of the included crops in the regional landscape (the biggest loss in production being rice with a deficit of around 100k euro from current produced values).

This finding highlights a critical gap in the applicability of current workflow data to the regional context. It calls for the integration of locally validated production data and economic impact models for key regional crops. Future phases of this assessment will aim to fill this gap, thereby improving the relevance and accuracy of the risk analysis for agricultural drought in Baixo Alentejo.

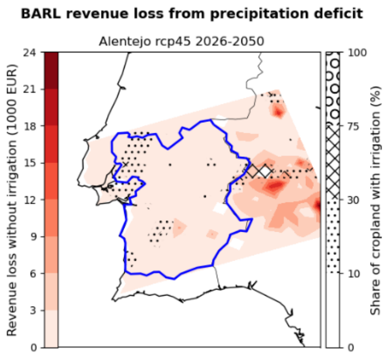

Figure 2-9 Projected production loss for Barley due to the deficit in precipitation, in % of current value

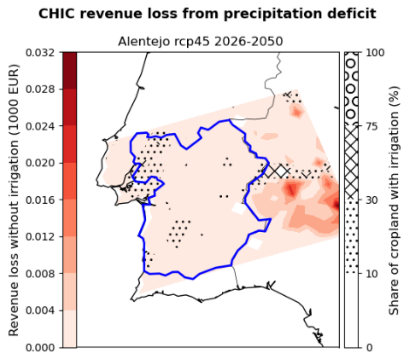

Figure 2-11 Projected production loss for Chickpea due to the deficit in precipitation, in % of current value

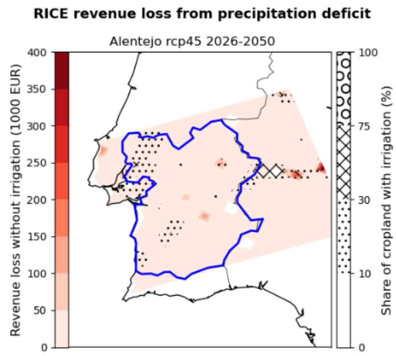

Figure 2-13 Projected production loss for Rice due to the deficit in precipitation, in % of current value

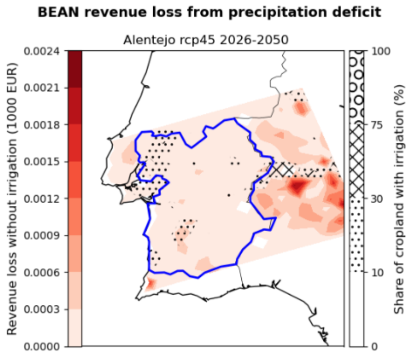

Figure 2-10 Projected production loss for Beans due to the deficit in precipitation, in % of current value

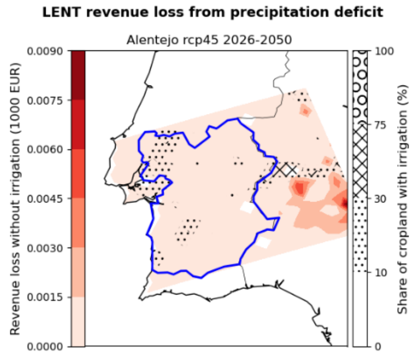

Figure 2-12 Projected production loss for Lentil due to the deficit in precipitation, in % of current value

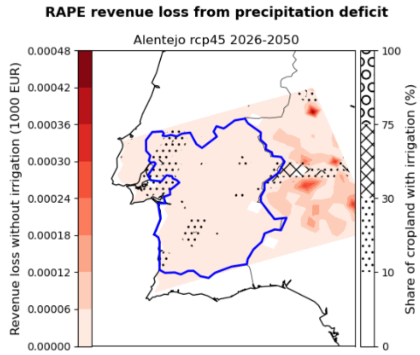

Figure 2-14 Projected production loss for Rapeseed due to the deficit in precipitation, in % of current value

2.3.2 Workflow #3 - Heatwaves

2.3.2.1 Hazard assessment - Heatwaves

The hazard assessment started with the analysis of historical vs. future hazard data for the number of occurrences of heatwaves according to the EuroHEAT definition of heatwaves – 3 or more consecutive days of temperatures above the 90th percentile for that region. The data encompasses 2 different time periods, a near future (2016-2045) and distant future (2046-2075), and uses EuroCORDEX data for RCP 4.5 and RCP 8.5 emission pathways. The assessment is divided into the administrative Freguesias (Civil parishes) of the Baixo Alentejo region.

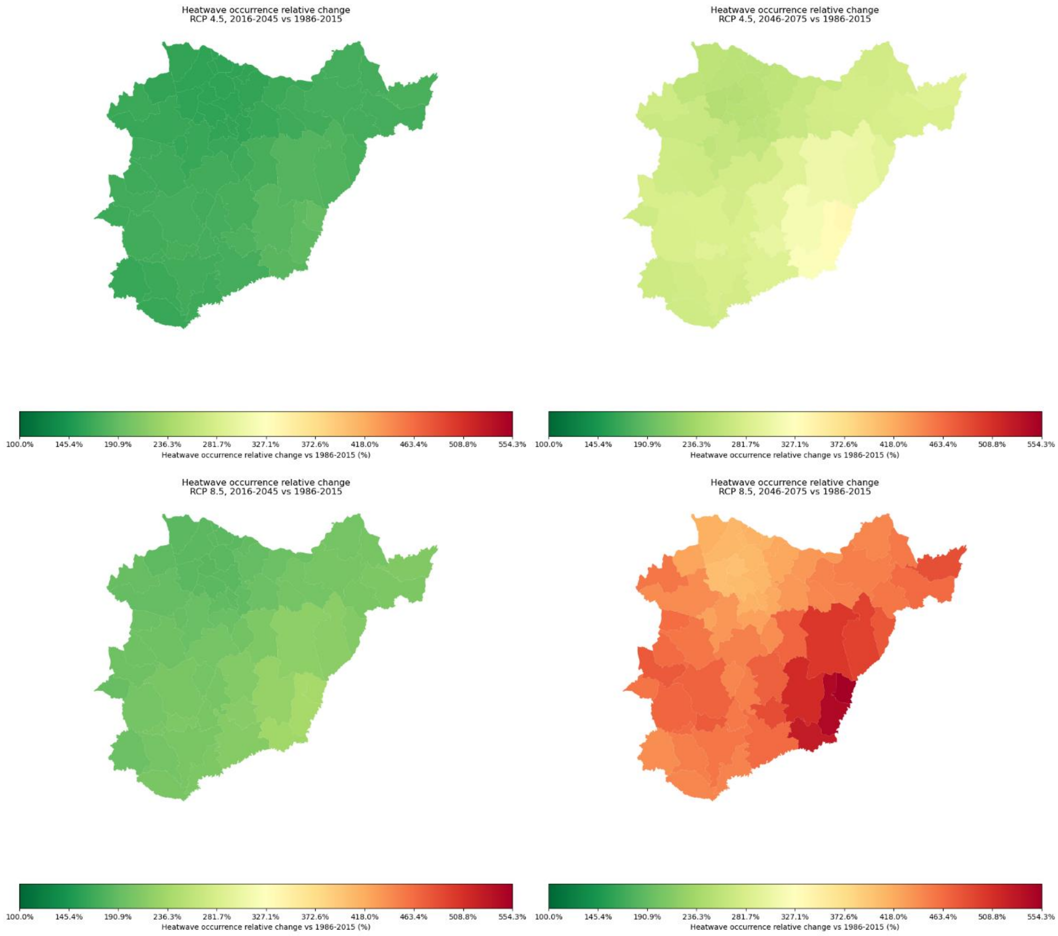

Figure 2-15 Heatwave occurrence evolution when compared to historical values

The southeastern part of the region is projected to be more severely affected by extreme heat, reaching an expected evolution of around 330% and 500% in the RCP 4.5 and 8.5 emission scenarios, respectively. The rest of the region appears to be projected to have a somewhat lower but still noticeable evolution, being pretty constant across the whole region except in the northern most part of the region.

This hazard data was also classified to a 1-10 hazard magnitude level for later risk assessments regarding demographic vulnerability data; to be used on the risk assessment matrix presented in this workflow. This classification into hazard magnitude levels is depicted in Figure 2-16.

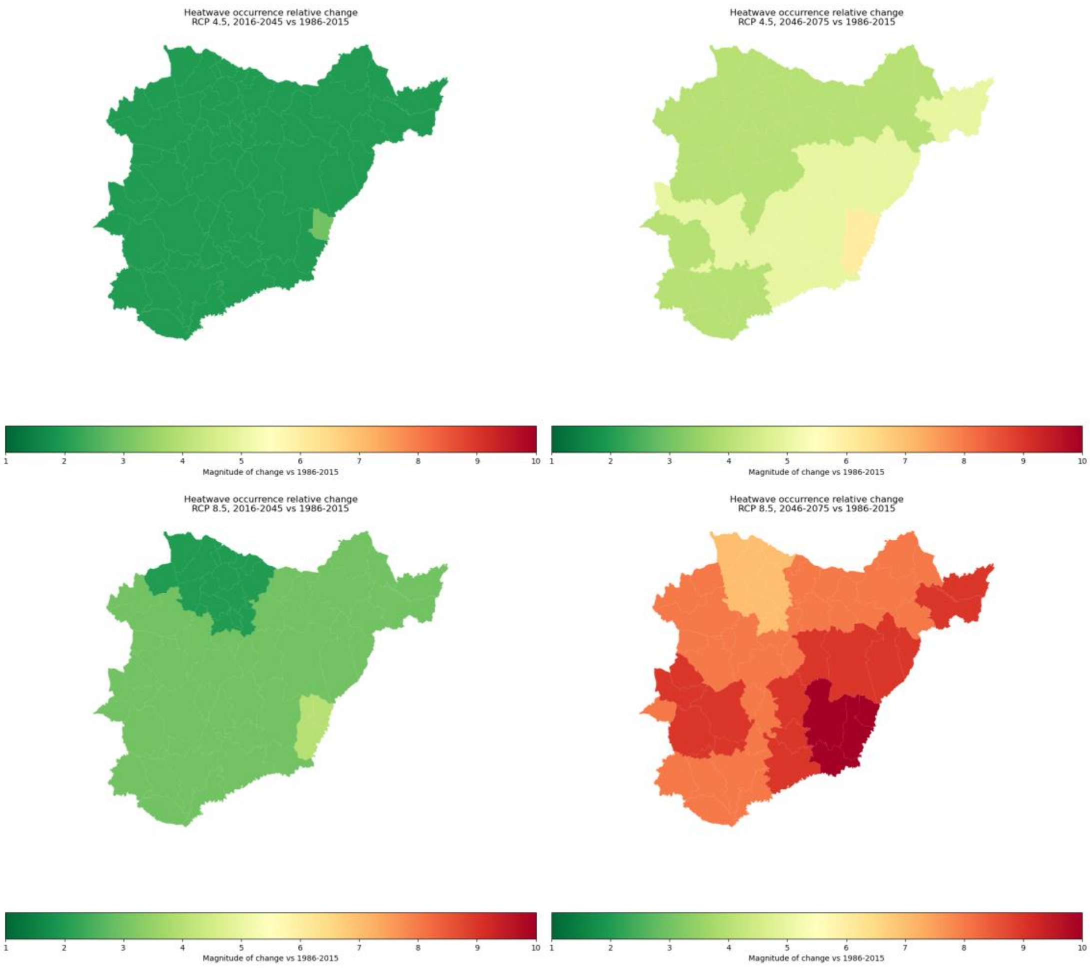

Figure 2-16 Heatwave occurrence evolution when compared to historical values reclassified to hazard classes

2.3.2.2 Risk assessment

As the heatwaves main focus is the health of the population, part of the risk calculation is the distribution of vulnerable population (infants below 5 years and seniors above 65 years of age), classified into a 1-10 magnitude, to properly calculate the 2-20 risk magnitude by adding to the heatwave magnitude calculated in the hazard assessment part of this workflow.

The magnitude levels are separated linearly into 10 magnitude levels, with any vulnerable population values of above 1000 people being a magnitude level 10 (to have meaningful civil parishes outside the region's most populated city of Beja)

The population distribution was sourced from the WorldPop database for age and sex structures, which presents an automated estimative of the last Census data; so, while not being 100% correct, it provides a pretty accurate estimative of the geographical distribution of the region's population.

This vulnerable population data is depicted in the graph on Figure 2-17.

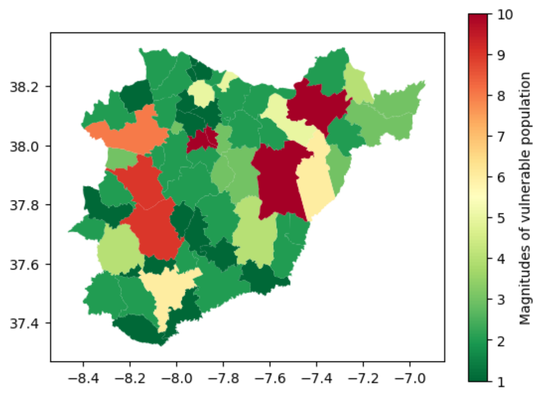

Figure 2-17 Vulnerable population, classified into 10 magnitude levels

Now adding the vulnerability magnitude related to vulnerable population with the previously calculated heatwave evolution hazard magnitude, according to the 5-level risk matrix depicted in the CLIMAAX Handbook, which assigns a risk level to the sum of two magnitude levels, the hazard and the vulnerability one, we obtain the plot in Figure 2-18.

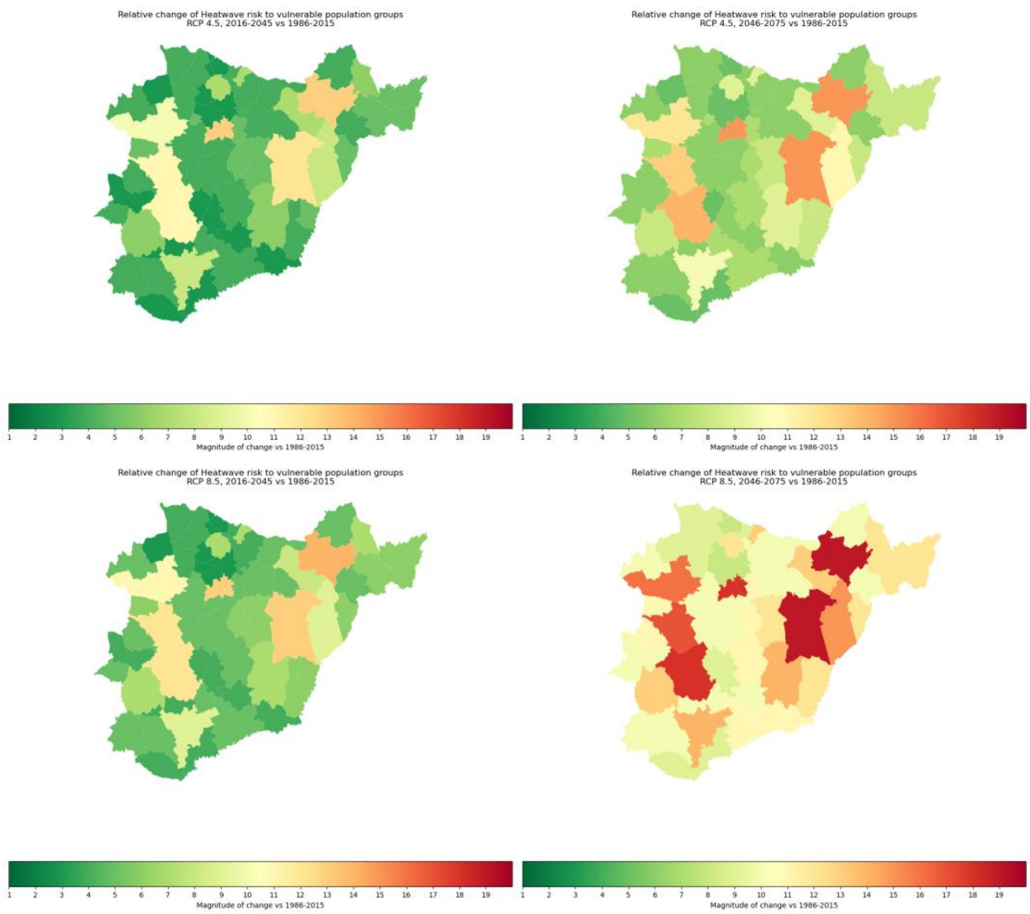

Figure 2-18 Risk magnitude levels, separated by civil parish of the Baixo Alentejo region

From this analysis, it is evident that the risk to vulnerable populations is very high in six civil parishes (Moura, Beja, Castro Verde, Aljustrel, Serpa, and Ferreira do Alentejo), highlighting the significant vulnerability of this region to future heatwaves. As a predominantly rural area with numerous villages scattered across the territory where the population is ageing this vulnerability may also have socioeconomic dimensions, which warrant further in-depth study with local data during Phase 2.

The risk posed by the urban heat island effect — stemming from the high reflectance of urban zones due to building materials that reflect electromagnetic radiation, resulting in elevated land surface temperatures in more urbanized city areas — can exacerbate the adverse health impacts of heatwaves on the population, particularly if people live or spend time in zones with high land surface temperatures.

Several strategies can mitigate the urban heat island effect, such as incorporating green spaces and trees into the urban landscape, which reduce the effect and provide shade. To support planning and strategizing efforts to minimize this phenomenon, Figure 2-19 presents a mapping of the historical mean Land Surface Temperature (LST) values for the summer of 2024 in the residential zones of the city of Beja—one of the highest-risk civil parishes for vulnerable population groups and undoubtedly the most populated. Figure 2-20 provides a histogram of the LST values for the same period and city.

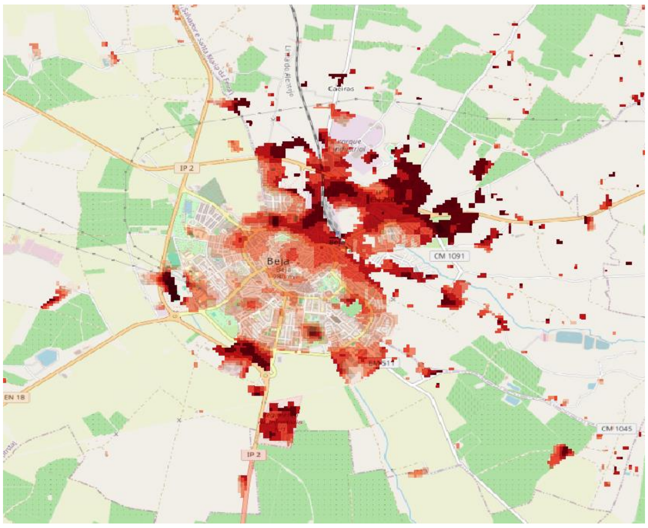

Figure 2-19 LST mean values for the summer of 2024, residential zones of the city of Beja

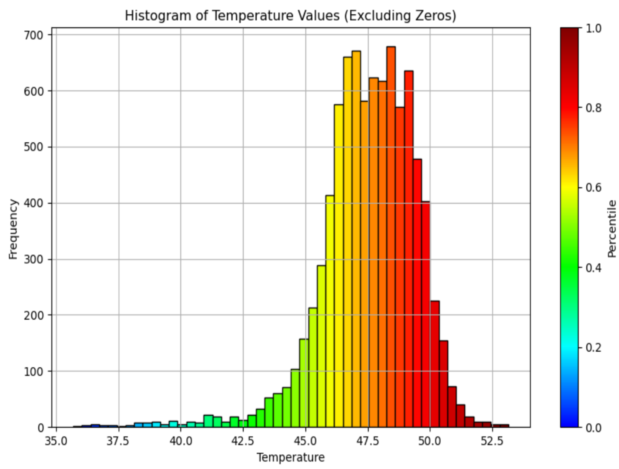

Figure 2-20 Histogram of the LST values depicted in Figure 2-19

2.3.3 Workflow #3 - Wildfires

2.3.3.1 Hazard assessment - Wildfires

The wildfire hazard assessment for Baixo Alentejo, covering the period 2021–2040 under RCP 4.5 and RCP 8.5 scenarios, utilized the CLCom_CCLM regional climate model alongside a machine learning-based workflow. However, results for the region were suboptimal due to limitations in the model's performance.

A key issue was the low volume of historical burnt area in Baixo Alentejo, which resulted in class imbalance during training and a low recall rate in fire risk prediction. The lack of sufficient positive fire events reduced the model's ability to detect true fire-prone zones, compromising its effectiveness for this specific region.

To address this, a new nationwide fire prediction model is being developed. This revised approach includes forced class balancing and the incorporation of a broader, Portugal-wide dataset to enhance the model's generalization and predictive accuracy. Additional refinements to model parameters and training methods are underway.

Figures 2-21 and 2-22 illustrate predicted fire risk under RCP 4.5 and RCP 8.5, respectively, while Figure 2-23 shows the land cover classification used in the model, highlighting key fuel types such as agroforestry, shrubland, and dryland agriculture. These land uses influence wildfire dynamics through fuel continuity and ignition potential.

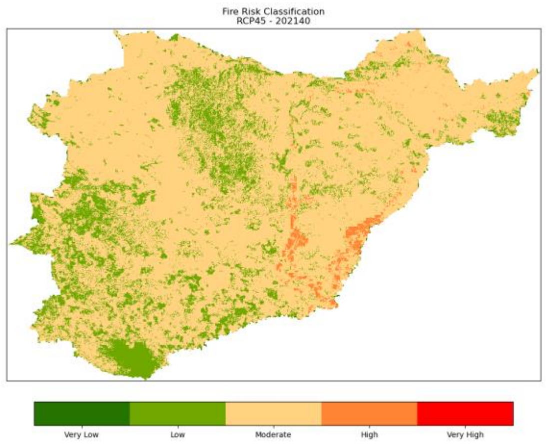

Figure 2-21 Fire risk prediction for the timeframe of 2021-2040, according to RCP 4.5

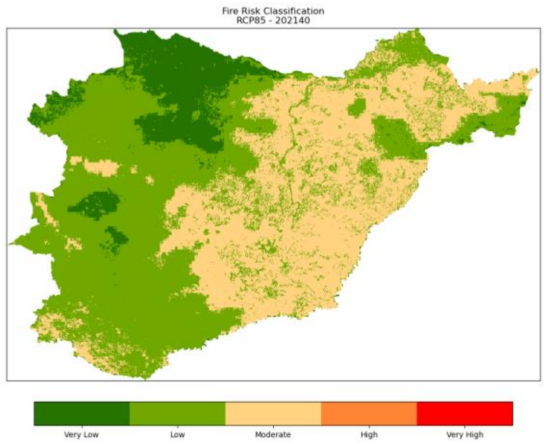

Figure 2-22 Fire risk prediction for the timeframe of 2021-2040, according to RCP 4.5

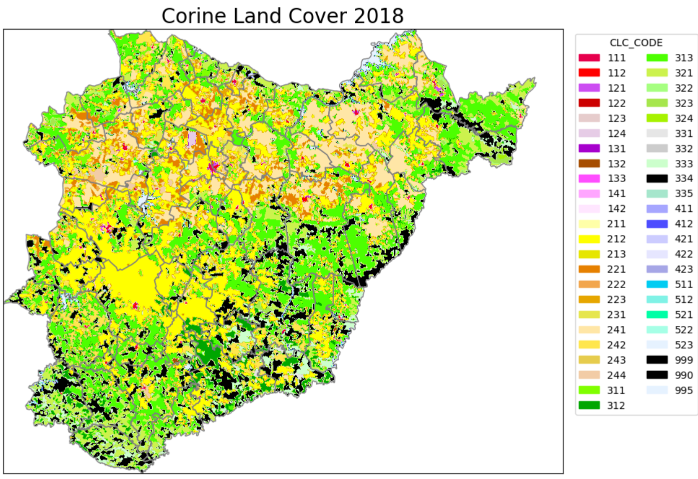

Figure 2-23 Corine Land Cover dataset for Baixo Alentejo

Although initial results offer some spatial insight, current model limitations underline the need for improved calibration and region-specific validation, which will be pursued in subsequent project phases.

2.3.3.2 Risk assessment - Wildfires

The risk assessment for wildfires will be further developed in Phase 2, based on a refinement of the approach initiated in Phase 1.

2.4 Preliminary Key Risk Assessment Findings

2.4.1 Severity

The risk analysis highlights three major hazards—droughts, wildfires, and heatwaves—as the most pressing climate-related challenges in Baixo Alentejo.

Droughts are persistent and intensifying, with clear impacts on agricultural production, water resource management, and soil degradation. Although the risk-modelling results in low monetary loss values for available crop types, this is due to a misalignment between CLIMAAX workflow crop datasets and the region's main agricultural outputs (e.g., olives and vineyards). Nonetheless, precipitation deficits and evapotranspiration trends point to severe water stress across the territory.

Wildfire risk is also increasing, but model performance in Phase 1 was limited. The machine learning-based prediction model underperformed due to class imbalance in the regional training data, resulting from a historically low number of recorded fire events. Despite these modelling constraints, contextual evidence and stakeholder feedback support the classification of wildfires as a high-severity risk.

Heatwaves are becoming more frequent and intense, and they act as compounding factors that amplify drought and wildfire risk. Results from the CLIMAAX heatwave workflow confirm the region's growing exposure to extreme heat events, with projections indicating significant increases in both frequency and duration. Vulnerable groups such as the elderly and very young children are particularly at risk.

2.4.2 Urgency

All three risks are already manifesting and are expected to worsen within the next 20–30 years. Drought and wildfire impacts follow a seasonal pattern but are increasingly persistent, while heatwaves are becoming both longer and more intense.

Efforts to address regional aridity through artificial irrigation have been ongoing for decades, particularly under the development of the Alqueva Multipurpose Project, which significantly expanded water availability through large-scale infrastructure. Managed by EDIA, this investment has transformed portions of Baixo Alentejo's agricultural landscape, reducing dependence on rainfall for high-value crops. However, the spatial coverage of irrigation remains uneven, and future climate conditions may outpace current system capacities. Continued investment and adaptation of irrigation infrastructure are therefore crucial to mitigate growing water stress and ensure resilience of agricultural systems.

The urgency of action is high. Adaptive responses are needed in the short to medium term to safeguard water resources, reduce fire fuel loads, and protect vulnerable population groups. While drought is a slow-onset hazard, wildfires and heatwaves present more acute and sudden impacts, underscoring the need for early warning systems and rapid response protocols.

2.4.3 Capacity

Several regional initiatives have already been implemented, including measures outlined in the Baixo Alentejo Intermunicipal Plan for Climate Change Adaptation (PIAACBA), in the municipal PARs, and in sectoral projects in water efficiency and fire prevention. All these actions have been coordinated and led by CIMBAL, through partnerships with relevant regional stakeholders such as EDIA, ICNF, and ANEPC.

Building on the regional initiatives already developed and currently underway, there is a strong objective to enhance technical capacity of stakeholders and institutions at the municipal level. This includes expanding access to climate-relevant data, improving the ability of technical staff to interpret and apply model outputs, and fostering the use of interoperable data platforms to support evidence-based decision-making. Training programmes and knowledge exchange mechanisms will also play a central role in supporting effective cross-sectoral planning and the implementation of robust adaptation strategies throughout Baixo Alentejo.

In the course of the project, and throughout the execution and implementation of its various phases, greatly motivated by the involvement of the 13 municipalities of Baixo Alentejo and the stakeholders with whom we will work—previously identified based on their sector of activity—the planned work sessions will also serve the purpose of equipping and providing the participating professionals with enhanced knowledge and awareness. This will enable them, in the performance of their various roles, to implement and develop actions/measures aimed at mitigating and adapting to climate change, as well as preventing and avoiding environmental climate risks.

2.5 Preliminary Monitoring and Evaluation

The first phase of the CRA enabled a structured, regionally contextualized exploration of climate risks, while revealing key technical and data-related limitations.

Most notably, the CLIMAAX workflows showed limited applicability for Baixo Alentejo's agricultural profile, with many relevant crops missing from available models. The wildfire hazard workflow also yielded underperforming results due to low historical fire records, which reduced recall in the machine learning model. These issues are being addressed through the development of a national model with better class balance.

Stakeholders provided valuable input during the initial workshop and supported the prioritization of heatwaves, droughts and wildfires. There was also early identification of emerging risks—such as strong winds and extreme precipitation—that may require closer monitoring in future phases.

Going forward, the CRA will benefit from:

- Integration of local agronomic datasets and refinement of existing workflows to better reflect Baixo Alentejo's crop profiles;
- Enhancement of the national wildfire prediction model, incorporating forced class balancing and broader spatial datasets;
- Expansion of stakeholder engagement to support the co-development of solutions across sectors;
- Integration of local datasets, particularly for agriculture and vulnerability;
- Expansion of stakeholder representation, including civil society and technical institutions;
- Calibration and validation of risk models using region-specific inputs;
- Continued institutional commitment to mainstream climate risk into planning and decision-making.

These improvements will be essential for ensuring the effectiveness of future phases and the overall success of the CRA process in Baixo Alentejo.

3 Conclusions Phase 1- Climate risk assessment (1 page)

The Phase 1 Climate Risk Assessment for the Baixo Alentejo region has established a critical foundation for understanding and responding to the region's primary climate-related hazards: **agricultural droughts, wildfires, and heatwaves**. This phase employed the CLIMAAX methodological framework to identify priority risks, assess hazard exposure and vulnerability, and engage stakeholders in the co-development of knowledge to inform future adaptation planning.

The main **findings** underscore the **growing severity and urgency** of all three climate risks:

- **Agricultural droughts** are exacerbated by declining precipitation and high evapotranspiration rates, threatening the region's heavily agriculture-dependent economy. However, the workflow's limited representation of key crops such as olives and vineyards reduced the accuracy of impact assessments.
- **Wildfire risk** is increasing due to changing land use, high fuel loads, and extreme heat, yet the machine learning model underperformed because of limited historical burn data. Model refinement through a national dataset is underway.
- **Heatwaves** emerged as a compounding hazard with significant impacts on public health, especially among vulnerable populations. The risk was particularly acute in municipalities with high elderly populations and urban heat island effects, as observed in Beja.

Key **challenges** identified during this phase include:

- Limited compatibility between CLIMAAX datasets and local agricultural realities.
- Underperformance of wildfire models due to data imbalance.
- Early-stage stakeholder engagement, requiring broader participation for inclusive planning.
- Scarcity of high-resolution local vulnerability and socio-economic data.

Despite these challenges, the **CLIMAAX framework provided a robust structure** for preliminary risk identification and facilitated a participatory approach through initial workshops. The findings have clarified where methodological refinements and deeper data integration are needed, notably in:

- Adapting workflows with region-specific datasets,
- Strengthening predictive models,
- Expanding institutional and technical capacity for risk-informed decision-making.

This first phase concludes that **Baixo Alentejo is already facing measurable climate risks** and that adaptive actions must be accelerated to build long-term resilience. The findings will directly inform future phases, focusing on model improvement, co-development of adaptation pathways, and mainstreaming climate risk into regional and municipal planning.

4 Progress evaluation and contribution to future phases

Table 4-1 Overview of key performance indicators

Key performance indicators	*Progress*
Submission of all 5 deliverables	1/5 (20%)
At least 2 different workflows applied successfully during phase 1	2/2 (100%)
At least 2 different workflows applied successfully during phase 2	0/2 (0%)
5 of climate adaptation actions implemented based on updated regional adaptation plans	0/5 (0%)
6 of stakeholder meetings, workshops, and consultations held	1/6 (16%)

Table 4-2 Overview of milestones

Milestones	*Progress*
10% more area covered in phase 3	0/10 (0%)

5 Supporting documentation

5.1 Workflow Result Archives

Workflow #1 – Agricultural Drought

Filename: agricultural-drought-results.zip

Contains projected yield loss maps, projected revenue losses and relevant spreadsheets related to the agricultural drought workflow under RCP 4.5 for the 2026–2050 period.

Workflow #2 – Heatwaves

Filename: heatwaves-result.zip

Includes hazard and vulnerability maps produced in the heatwave workflow, under RCP 4.5 and RCP 8.5 for two time periods, one short-term and another long-term future periods.

Workflow #3 – Wildfires

Filename: wildfire-result.zip

Includes maps, raster images and visualizations related to the wildfire workflow, under RCP 4.5 and 8.5 for three time periods, a short-term, a medium-term and a long-term future periods.

5.2 Model and feature Dataset

Wildfire Model and Feature Data

Filename: wildfire-model-and-features.zip

Includes the training data and the latest version of the model used for predicting the wildfire hazard during the wildfire workflow

5.3 Repository Access

All outputs listed above have been uploaded to the Zenodo repository under the CLIMAAX entry for Baixo Alentejo:

Zenodo Repository Link: https://doi.org/10.5281/zenodo.15112947
DOI: 10.5281/zenodo.15112947

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