CLIMAAX
climate ready regions

Deliverable Phase 1 – Climate risk assessment

CAP HM

Sweden, Håbo municipality

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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

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Abbreviations and acronyms

Abbreviation / acronym	Description
C3S	Copernicus Climate Change Service
CAP HM	Climate Adaptation Program for Håbo Municipality
CDS	Climate Data Store
CHELSA	Climatologies at high resolution for the earth's land surface areas
CLIMAAX	CLIMAte risk and vulnerability Assessment framework and toolboX
Climate-ADAPT	The European Climate Adaptation Platform
CORINE	Coordination of Information on the Environment, a European Commission program
CRA	Climate Risk Assessment
DEM	Digital Elevation Map
EFFIS	European Forest Fire Information System
ERA5	European reanalysis
EuroHEAT	European Heat health information network
FSTP	Financial Support for Third Parties
GIS	Geographical Information System
GISCO-EU-DEM	Geographic Information System of the Commission – European Union - Digital Elevation Model
ICHEC-EC-EARTH	Irish Centre for High-End Computing - European community Earth System Model
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
KNMI-RACMO22E	Royal Netherlands Meteorological Institute – Regional Climate Model
LST	Land Surface Temperature
MKB	Miljökonsekvensbeskrivning (Environmental impact assessment)
ML-Model	Machine Learning model
MPI-M-MPI-ESM-LR	A Climate Model Chain
MSB	Myndigheten för Samhällsskydd och Beredskap (Swedish Civil Contingencies Agency)

NUTS	Classification of Territorial Units for Statistics (NUTS, for the French nomenclature d'unités territoriales statistiques)
PBL	Plan och ByggLagen (Planning and building act)
RCA4	Regional Climate Model
RCP8.5/RCP4.5	Climate Scenarios
SMHI	Swedish Meteorological and Hydrological Institute
UTCI	Universal Thermal Climate Index
WMO	World Meteorological Organisation

Executive summary

Climate related hazards will affect Håbo municipality in several ways. Håbo is a small municipality in southern Sweden and is therefore exposed to a wide variety of hazards such as heavy rainfall, heatwaves, droughts, wildfires and snow blizzards. In the project Climate Adaptation Program for Håbo Municipality (CAP HM) these hazards are analysed and will lay the background for an action plan with the overall aim to create a climate resilient municipality.

The first phase of the project has just been concluded, in which global data has been used to analyse heavy rainfall, heatwaves and wildfires through the workflows created by the CLIMAAX project. The result show that the risk for all analysed hazards (heavy rainfall, heatwaves and wildfire) will increase in frequency and/or magnitude due to climate change. The result is, however, not specific enough to draw informed conclusions on which adaptive measures are needed and prioritized. The fine adjustments, local data and wider range of models that will be used in phase 2 is expected to provide a more specific result.

Stakeholder engagement and cooperation is vital to spread and gather information about possible impacts. CAP HM has reached out to both internal and external stakeholders to share results and collect input to improve the analyses and following action plan. The interest has so far been thin but is expected to increase in phase 2 and 3 of the project.

1 Introduction

1.1 Background

Håbo municipality is located in south of Sweden, just outside of Stockholm. Håbo is a municipality of 186,47 square kilometres with both rural and urban areas. The population is 22 985 people, which means that it is a relatively small municipality and a small municipal organization. Even though the organization is small, it is of high quality and competence thanks to being located close to large cities and universities. The past decades the population have been increasing, and the estimation is that this development will continue in the foreseeable future. This will increase the importance for a sustainable and resilient physical development of the municipality. As a municipal organization Håbo has the responsibility to plan and develop the municipality in a sustainable manner and to care for our citizens and industry. This entails e.g. physical planning, infrastructure, education, elderly care and social services.

Håbo faces multiple climate-related hazards. Bordering to lake Mälaren and with many hard-made surfaces, Håbo has a large risk of flooding when an extreme rainfall strikes. The risk for landslides and collapse due to conditions in the soil intensifies when the rainfall is heavy and experts give Håbo a risk level 3 on a 5-grades scale. Previously this year, main highways and roads in south of Sweden were totally blocked and inaccessible by snow blizzards. The provision of services such as elderly care and education to the rural areas are dependent on access to the road network. Håbo has large areas of both forests and agricultural land, which are both vulnerable to wildfires and droughts. At the same time Håbo municipality is growing in terms of population and industry, with expanding hard surfaces creating "heat islands". This makes our citizens, particularly our aging population, vulnerable to increased frequency, intensity and duration of heatwaves. This wide variety of hazards demands an equally wide variety of well-informed adaptive measures, which is why Håbo is participating in the CLIMAAX project.

1.2 Main objectives of the project

The objective of this project is to provide a climate- and risk assessment of high quality from which Håbo can analyse how the various hazards pose a risk to the municipality and improve the common understanding of the level of risk. Since Håbo municipality faces several climate-related risks this is of high importance to be able to prioritize and finance adaptive measures.

The expected results from the project are

Quantified risks

The study will provide a climate- and risk assessment of high quality from which it is possible to analyse how the various hazards pose a risk to the municipality. This will improve the understanding of the risks and the necessity of adaptive measures.

Improved collaborations

Having good data and background on how climate-related risks affect the municipality enables a broad discussion of risk and resilience. The dialogues with different stakeholders will have two main impacts:
- Stakeholders bring various knowledge of the impact of climate related hazards, as well as possibilities for adaptive measures. This enables a better risk assessment and adaptation plan.
- Stakeholders gain a higher understanding of climate-related risks, which will be a motivation to collectively address the adaptive measures.

Improved resilience

Having an advanced climate- and risk-assessment and the appropriate decision makers gathered will enable the municipality to identify relevant adaptive measures. Structures and routines will be put into place to deal with various risk situations when they arrive. This could e.g. be to set up a priority for road accessibility or routines for elderly care during heatwaves. At the same time preventative measures in the physical structures and operational functions of the municipality can reduce the impact from climate-related hazards. This could e.g. be to establish natural or technical solutions to reduce the waterflow from extreme rainfall in present and planned structures or prepare the citizens by providing information about responsibilities and available assistance in case of climate-related hazards.

Reduced costs

In the long term, preventing risk-situations can reduce future risk-managing costs. More resources can then be put into the continued creation of a sustainable municipality.

1.3 Project team

The core project team consists mainly of two people, a coordinator and an expert. The municipal sustainability strategist, Nina Aldén, is coordinating the project. The CRA is made by a subcontractor, Erik Engström from Goodpoint AB, who possess the necessary skills regarding both climate knowledge and data processing. Additional competences that are, so far, briefly involved in the project from the municipality are a GIS coordinator and a strategist from the Water and sanitation department.

1.4 Outline of the document's structure

This document begins with outlining the background, objectives and organization of the project in an introductory chapter. This is followed by a chapter that describes the different steps of the CRA made in this first phase of the project. The results are analysed and concluded in the 3: rd chapter, and suggestions for future phases are presented in chapter 4. Finally, the report shows a summary of supporting documents and references.

2 Climate risk assessment – phase 1

2.1 Scoping

2.1.1 Objectives

How the result will inform policy and decision making will depend on which climate risks are prioritized. Some risks concern new buildings and some concern existing buildings. Some actions are more physical, and some involve developing policies and routines. The result will, however, make out the basis of a general Climate adaptation program for the municipality. This program will show how the activities in the municipality are affected by climate change and how we can take adaptive measures with the main objective to increase the resilience of the municipality to be able to handle extreme weather and have preparedness.

Geographically the CRA is limited to the Håbo municipality area. In phase 1 global data provided in the CLIMAAX project will be used and in phase 2 local data. Stakeholders will play a small role in phase 1 due to time restraints, but phase 2 will provide large opportunities for stakeholders to engage.

2.1.2 Context

There are some prior climate risk assessments performed for the municipality, eg a heavy rainfall analysis with flooding risks, information about polluted soil and heat mapping. However, the result has not been taken care of due to lack of resources and internal structures.

Climate adaptation is a difficult issue to discuss in the broad arena that is necessary. This is mainly due to a lack of understanding of the concept and a lack of time and resources. The existing buildings are the most difficult to handle. This project addresses these problems. It provides a solid knowledge base from which the municipality can form dialogues, working structures and actions. It also enables extra resources to be placed on coordinating and addressing climate adaptation which puts the issue higher on the agenda.

Swedish law, Plan och bygglagen (PBL) regulates some aspects of the climate adaptation. An "MKB" (Environmental impact assessment) is mandatory in city planning, but the climate adaptation perspective is very limited. Strategic documents in the municipality are relevant, such as the sustainability strategy and the program for green structure. The regional administrative board has a climate adaptation strategy.

Internal resources that will contribute to the project will be the climate adaptation coordinator (the sustainability strategist), a person from the water and sanitation department, an ecologist and a GIS-coordinator. Besides these resources, a sub-contractor is engaged for expert knowledge on climate change and data analysis.

Several sectors within the municipal organization are affected by climate change in various ways.
Elderly care – dependent on access to road network and vulnerable to heatwaves.
Childcare and educational system – dependent on access to road network and vulnerable to heatwaves.
Infrastructure – vulnerable to floods and landslides
Parks and public areas – vulnerable to floods, and can make out adaptive measures
Water and sanitation – vulnerable to floods and landslides
Public buildings – vulnerable to floods, landslides and heatwaves
Land and property management – vulnerable to floods, droughts and fires

City planning – important to prevent floods, heat islands, land slides
Industry relations – communication of risk ownership and cooperation
Communications – spread and gather information
Risk management – merge CRA with ordinary risk management

There are currently no apparent outside influences on the problem. At this point in the project, there is need for more information to evaluate relevant adaptative measures, but nature-based solutions should be considered as they often address several hazards. Some adaptation interventions will probably be administrative, e.g. new routines or cooperations.

2.1.3 Participation and risk ownership

The participation in the CLIMAAX project has been announced through the municipality's official channels as well as internal channels. Relevant external stakeholders and representatives are land- and property owners, elderly organizations, Fire department, industry and civil society organizations. Stakeholders and citizens have been invited to express their interest through an online survey, placing them on our CLIMAAX e-mail list. A dialogue has been initiated with the fire department and their input have been important. By the end of phase 1 an external stakeholder dialogue took place, to inform about the results of the first CRA and gather input for the following phases. Besides the dialogue meeting, two public events will reach out to external stakeholders.

2.2 Risk Exploration

2.2.1 Screen risks (selection of main hazards)

The location of Håbo municipality in south Sweden at the rim of lake Mälaren makes the area affected by variations in the surface level of the lake. Although large fluctuations in the surface level are uncommon it could cause flooding in Håbo municipality. Heavy rainfall can occur everywhere, also in Håbo. The urban centre of Bålsta with much hard surface area is more vulnerable to heavy rainfall and the risk for flooding due to the downpour. The hard surface areas in Bålsta can also cause a heat island effect and worsen heat waves. The city centre also holds the highest concentration of vulnerable population such as the oldest age groups. The rural parts of Håbo municipality which is mostly made up of agriculture fields and forest is exposed to climate hazards such as draughts, pests and wildfires.

The CAP HM project will focus on the climate hazards heatwave, heavy rainfall and wildfire. Håbo municipality has so far not suffered from severe climate disasters, but a neighbouring municipality was recently affected by heavy rainfall that led to serious flooding.

With the ongoing global warming which in Sweden generally is twice as fast compared to the global average heatwaves are expected to become stronger and more frequent. At the same time the population in Håbo is growing so the amount of vulnerable people will also increase. With a warmer climate the events with extreme rainfall are expected to be more common and can cause flooding. In parallel droughts and wildfires will occur more often due to increased evaporation.

The CAP HM project has access to international sources such as IPCC, WMO, Copernicus and other EU-projects. At a national level Swedish agencies provide information and services and on a regional and local level the Swedish administrative boards and municipalities have done several assessments on different climate hazard and adaptations. The project aims to combine these different sources of information and data to derive more locally tailored climate risk assessments for the relevant hazards.

2.2.2 Workflow selection

2.2.2.1 Heavy rainfall

Heavy precipitation can cause most damage in urban city centres where the population density is high and ground, to a large extent, is covered by hard surfaces. Down pours can cause floodings which can damage for example buildings and vehicles. Heavy rainfall and floodings can also damage infrastructure such as roads and railways and cause damage everywhere, not only in city centres. Population groups extra vulnerable for flooding are people with restricted mobility, such as elderly and sick people, which makes facilities such as hospitals high risk areas.

2.2.2.2 Heat wave

Extreme temperatures effects everyone but extra vulnerable are small children, elderly and sick people. The effect is amplified in city centres where the heat island effect can add further increase the temperature.

2.2.2.3 Wildfire

Fire in vegetation can pose severe danger to people and damage to buildings and infrastructure and result in excessive economic losses for businesses in forestry and agriculture. In urban areas the concentration of exposed people, buildings and infrastructure are higher but in the countryside the amount of burnable vegetation is higher.

2.2.3 Choose Scenario

For choice of climate scenarios both low and high emission scenarios are useful, because using several different scenarios can give knowledge about the robustness of the analysis and the results.

2.3 Risk Analysis

2.3.1 Heavy rainfall

Table 2-1 Data overview Heavy rainfall

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
GCM: ICHEC-EC-EARTH RCM: KNMI-RACMO22e RCP8.5 1976-2005 2041-2070 Not bias corrected Duration: 3 and 24 hours Intensity: 100 mm Frequency: 5 years	Open street map schools and hospitals	Open street map schools and hospitals	Change/shift in return period for extreme events. Risk for different areas in the region and specifically for schools and Hospitals.

2.3.1.1 Hazard assessment

For the heavy rainfall hazard assessment in phase 1 of the CAP HM project global climate model ICHEC-EC-EARTH and the regional climate model KNMI-RACMO22E were used. Phase 2 will probably test the MPI-M-MPI-ESM-LR/SMHI-RCA4 model chain to evaluate if that model combination better can reproduce extreme precipitation in Sweden.

Both RCP4.5 and RCP8.5 scenarios were used in the assessment. 1976-2005 was selected as historical time period and 2041-2070 as future time period. Bias corrected climate data was not used in phase 1 but is possible for phase 2.

Climate data was downloaded for the rain event durations of 3 and 24 hours respectively. The thresholds were set to 100 mm during 24 hours with a return period of 5 years in the assessment. These selected thresholds are probably a bit too high for Sweden so for phase 2 the plan is to lower the rain amount to a value between 50-100 mm during 24 hours with a return period of 5 year.

In the first step a point in the city of Bålsta in Håbo municipality was selected with the coordinates 59.56 latitude and 17.52 longitude.

The workflow gave no change in either magnitude or frequency for the future climate scenario period 2041-2070. The expectation was an increase in either magnitude or frequency or both. Probably this surprising result could be a result of the selection of climate model or a too high threshold for heavy rain events in Sweden.

A rectangular geographical area around the Mälardalen region in Sweden was selected for the rest of the assessment.

The project visualized the projected 3-hour precipitation event with a return period of 10-years for the Mälardalen region for the future period of 2041-2070 which seemed to be around 15-30 mm (Figure 2-1). The relative change compared to the baseline 1976-2005 was also plotted but showed no clear trend.

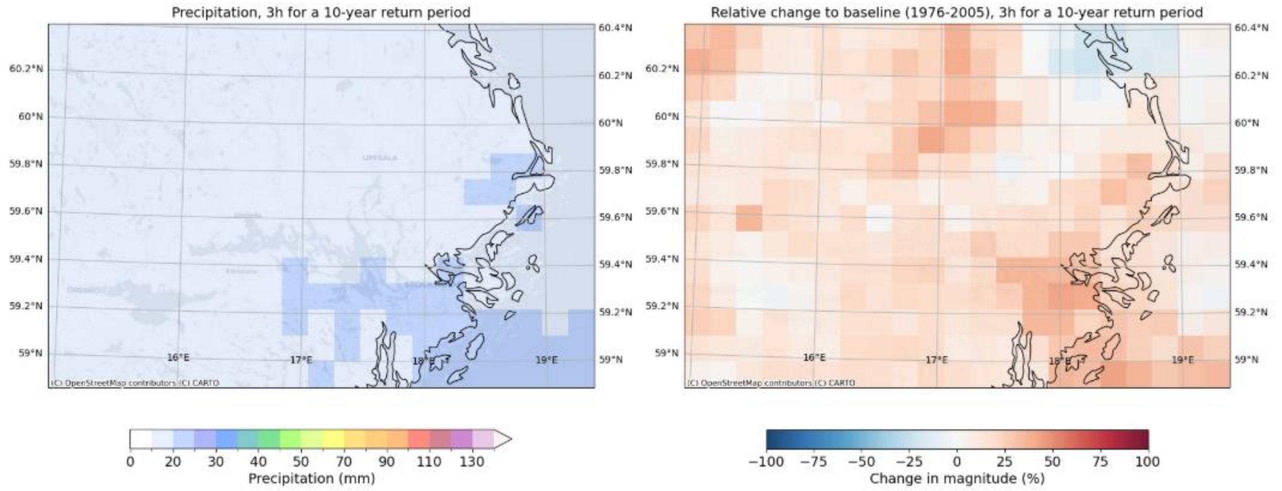

Figure 2-1 Projected 3-hour precipitation event with a return period of 10-years for the Mälardalen region for the future period of 2041-2070 (right) with RCP8.5. The relative change compared to the baseline 1976-2005 (left)Title of the figure

The project plotted the precipitation amount versus the return period for a 3 (*Figure 2-2*) hour event. For a 3-hour event the return period for a 25 mm rain changed from around 80 years for the historical period to around 40 years for the scenario period. For a 24-hour event the return period for a 60 mm rain changed from around 50 years for the historical period to around 45 years for the scenario period (figure in Zenodo).

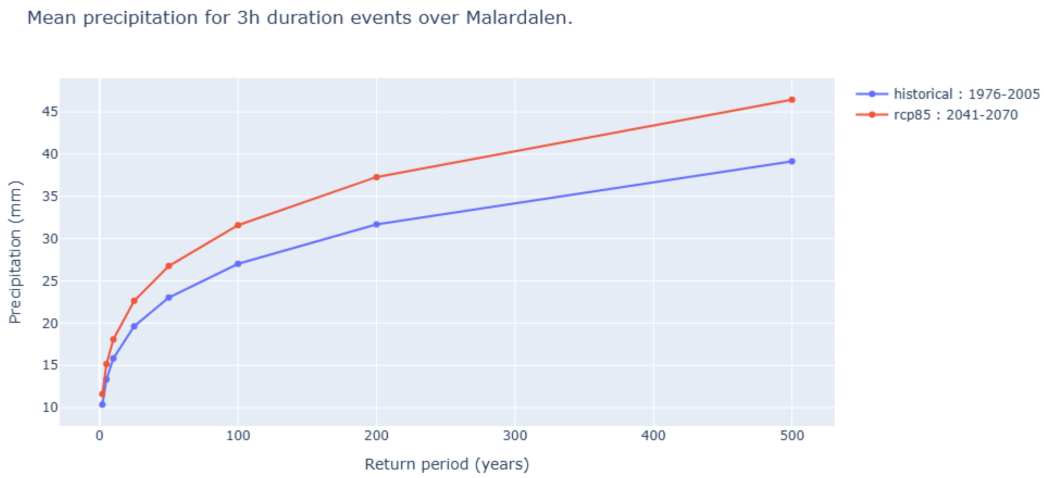

Figure 2-2 Precipitation amounts versus the return period for a 3-hour event.

Future climate data was used to study the possible annual maximum precipitation for 3 hours and 24 (Zenodo) hours duration in Bålsta, which resulted in 10-15 mm and 20-30 mm, respectively. No trend could be seen.

2.3.1.2 Risk assessment

In the risk assessment the return period for 100 mm rain in 24 hours was plotted for the current period 1976-2005 and the projected period 2041-2070 under the RCP8.5 scenario (Zenodo). The return period was something between 100 and 500 years. No clear change could be seen.

Then the change in the return period for the two periods 1976-2005 and 2041-2070 was plotted together with critical infrastructure such as schools and hospitals (Figure 2-3). If the analysis had shown a clear trend in the change of return period, it would have been valuable to see most exposed schools and hospitals.

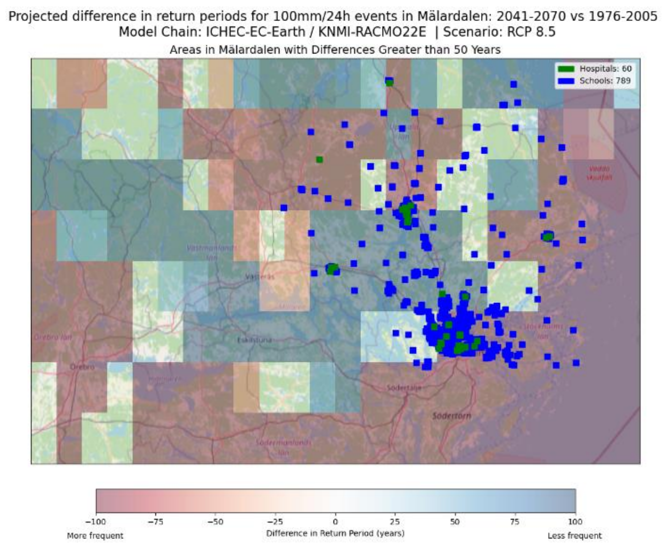

Figure 2-3 Change in the return period for the two periods 1976-2005 and 2041-2070 was plotted together with critical infrastructure such as schools (blue) and hospitals (green).

2.3.2 Heat wave

Table 2-2 Data overview Heat wave

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
EuroHEAT heat wave days CDS RCP4.5 and RCP8.5 SMHI ptHBV monthly mean temperature Climate-ADAPT RSLab	Worldpop Hub	Heat island mapping	Heatwave risk for vulnerable population groups.

2.3.2.1 Hazard assessment

For the heatwave hazard assessment, the EuroHEAT method was used based on heatwave days from CDS with a grid resolution of 12x12 km for the years 1986-2085 (Hans Hooyberghs (VITO), Heat waves and cold spells in Europe derived from climate projections, 2025). The future projection data was based on both the RCP4.5 and RCP8.5 climate scenarios. The assessment was done both with the European-wide heatwave definition and the national Swedish heatwave definition. The European-wide heatwave definition is days in which the maximum apparent temperature (Tappmax) exceeds the threshold (90th percentile of Tappmax for each month) and the minimum temperature (Tmin) exceeds its threshold (90th percentile of Tmin for each month) for at least two days. The national Swedish heatwave definition used in this assessment is a day on which daily maximum temperature is equal to or exceeds 30 °C for 5 consecutive days (Hans Hooyberghs (VITO), Heat waves and cold spells in Europe derived from climate projections documentation, 2023).

First a point in the city centre of Bålsta in Håbo municipality was selected. Historical data showed no large geographical variation in the number of heatwave occurrence for the region of interest, Mälardalen. There is a slight increase over the Baltic Sea compared to over land.

When assessing change over time for the occurrence of heatwave days for the point location in Bålsta using the national definition a clear increase can be seen, both for the RCP4.5 and RCP8.5 scenarios (*Figure 2-4*). From around 5 heatwave days each year in the present climate to 10-15 days for RCP4.5 and around 25 days for RCP8.5 in the end of this century.

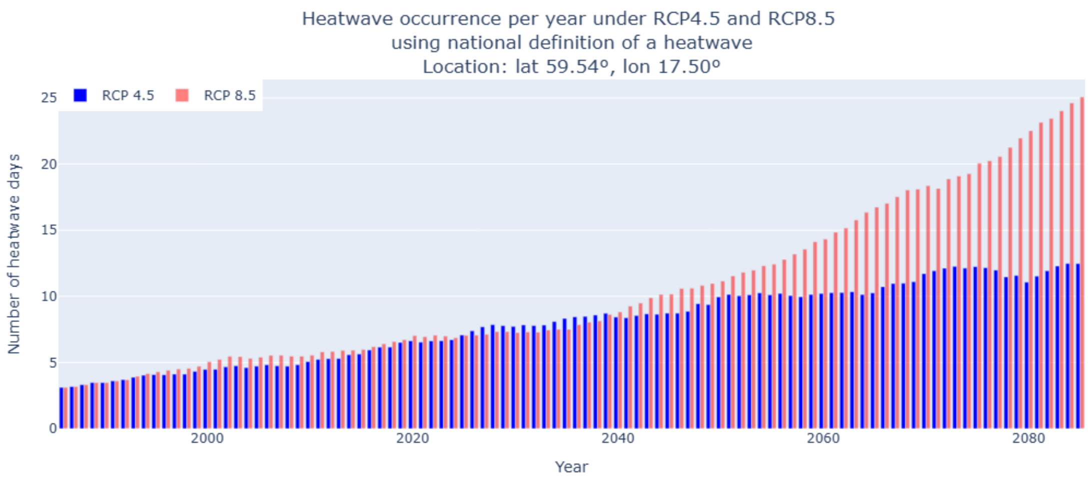

Figure 2-4 Change over time for the occurrence of heatwave days for the point location in Bålsta using the national definition and the RCP4.5 (blue) and RCP8.5 (red) scenarios.

2.3.2.2 Risk assessment

The heatwave risk assessment attempted to answer the questions:

- What are the problematic areas? (most overheated areas)
- Who or what is exposed?

To understand the influence of climate change on the probability of heatwave occurrence in the future relative to the present climate the results from the heatwave hazard assessment and information on the future occurrence of hot days at NUTS2 level from Climate-ADAPT (Climate ADAPT, 2025) based on the ERA5 dataset delivered by the Copernicus Climate Change Service (C3S) were used.

The services from Climate-ADAPT use the Universal Thermal Climate Index (UTCI) days index which gives the number of days with either strong, very strong and extreme heat stress. The time-evolution of UTCI for the NUTS2 region Östra Mellansverige doesn't show a large trend, maybe a small increase during the last decades (*Figure 2-5*).

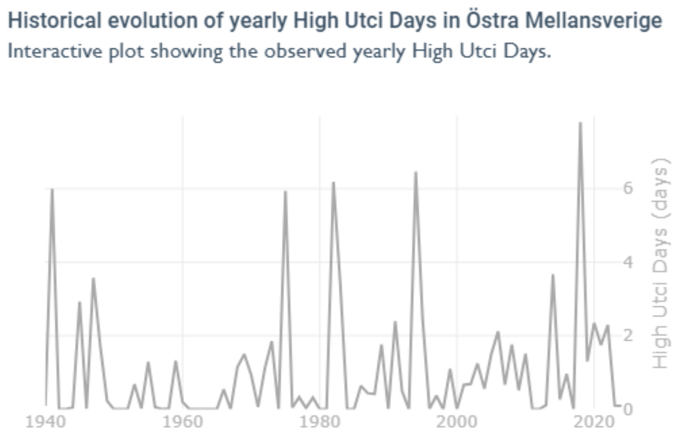

Figure 2-5 Historical evolution of yearly high UTCI days in Östra Mellansverige.

The projected future evolution of heatwave days in Östra Mellansverige based on the RCP4.5 and RCP8.5 scenarios shows an increase from occasional yearly events in present climate to around 10 days each year in the end of this century for RCP4.5 and between 20 and 25 days each year for RCP8.5 (*Figure 2-6*).

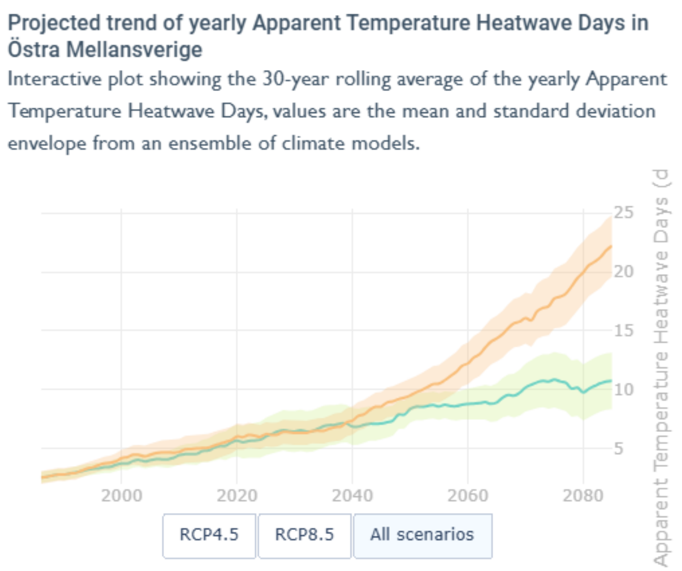

Figure 2-6 Projected trend of yearly apparent temperature heatwave days in Östra Mellansverige.

The yearly variation for tropical nights in Östra Mellansverige was evaluated (*Figure 2-7*). The definition of tropical nights is when daily minimum temperature remains above 20°C. No clear trend could be seen except for 2018 which was an extremely warm summer in Sweden.

Projections of future evolution of yearly tropical nights in Östra Mellansverige shows a clear increase after 2050 and for the second half of the century. The increase is small for the scenario RCP4.5 but between 5 to 10 night per year in the end of this century.

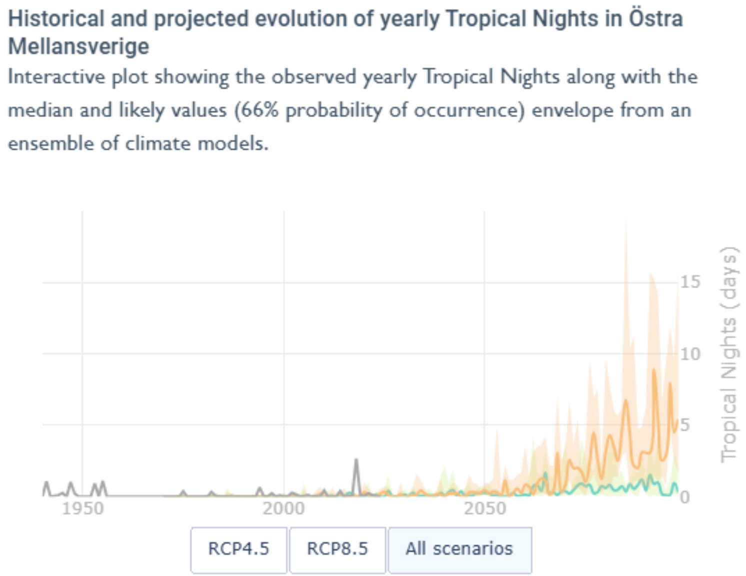

Figure 2-7 Historical and projected evolution of yearly tropical nights in Östra Mellansverige.

During heatwaves urban areas are more exposed due to the heat island effect because much of the surface in urban areas is covered by dark hard material such as asphalt and concrete that absorb more of the energy in the incoming solar radiation. The energy is then re-emitted as heat. To study this effect satellite-derived data based on land surface temperature (LST) calculated from Landsat 8 or 9 imagery (spatial resolution: 15-30m; at 8-16 days interval) is used.

The satellite data has very high resolution, which makes it possible to only download a short time period due to the large file size of the data. Therefore, there was a need to make sure to choose a time period with the highest temperature to study heatwaves. For this monthly mean temperature data for the years 2014-2024 for two grid cells in Bålsta from the ptHBV dataset from SMHI (SMHI, 2025) was used. The ptHBV dataset has monthly data from 1961 until now covering Sweden with a grid resolution of 4x4 km. The temperature was plotted as a timeline and showed that the highest monthly mean temperature was measured in Bålsta in July 2018. Satellite data was then downloaded for an area represented by a box with the coordinates longitude 18.65 -18.85 and latitude 49.16-49.27 for the time period 2015-06-01 to 2015-08-31.

LST was calculated for the region of interest and classified into five temperature classes from 20 to 60 degrees Celsius. In phase 2 of the CLIMAAX project the thresholds for the classes cloud be adjusted to span the interval 15-50 degrees instead. These classes are plotted in the left panel of *Figure 2-8*.Data on vulnerable groups in the population was retrieved from WorldPop (University of Southhampton, 2025) for the ages 0-80 years in Sweden for both males and females. The density of vulnerable population groups for the age groups 0-5 and 65-80 years were plotted in the right panel of *Figure 2-8*.

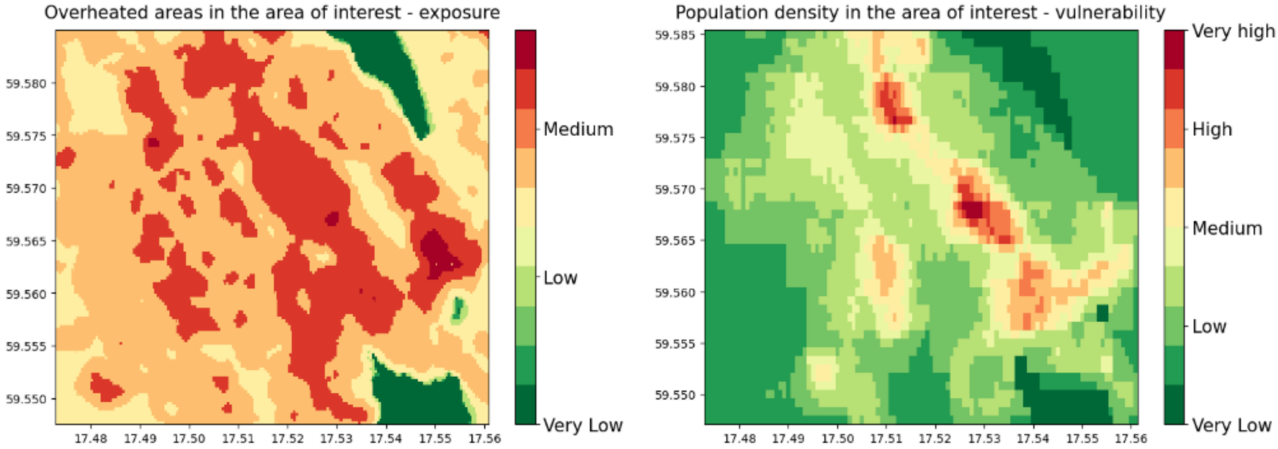

Figure 2-8 Classification of overheated areas in Bålsta (left). Density of vulnerable population groups for the age groups 0-5 and 65-80 years (right panel).

The overheated areas and density of vulnerable population groups were combined in a 10x10 risk matrix (*Figure 2-9*).

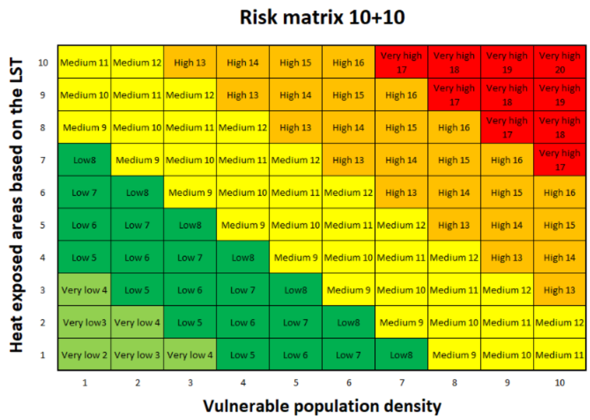

Figure 2-9 10x10 heatwave risk matrix for overheated areas and density of vulnerable population groups.

The heatwave risk was calculated as the **exposure** (LST - areas that heat up most) **x vulnerability** (density of vulnerable population) based on historical data (*Figure 2-10*). In the figure the location of critical infrastructure such as schools and hospitals is plotted as blue dots. Other critical buildings could be interested to add to the assessment in phase 2 of the CLIMAAX project.

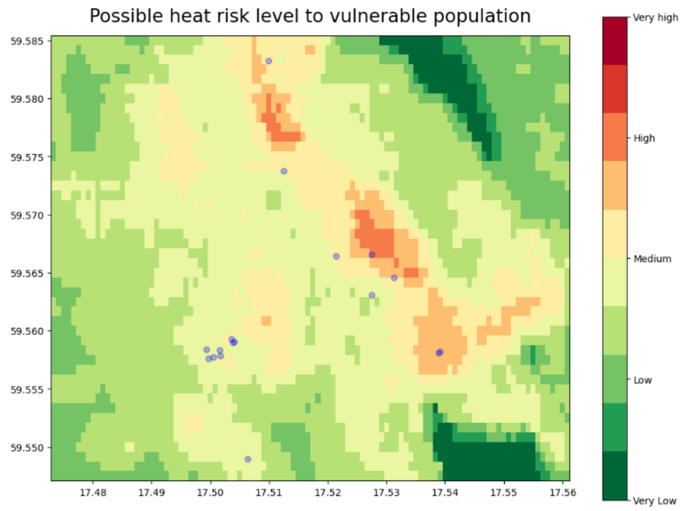

Figure 2-10 Heatwave risk for vulnerable population groups and critical infrastructure (hospitals and schools, blue dots).

2.3.3 Wildfire

Table 2-3 Data overview Wildfire

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
CHELSA Historical climate and RCA4 RCP8.5 2061-2080 EFFIS Corine landcover 2018 GISCO-EU-DEM	JRC data on population, economy and ecology.	Open street map data on hospitals, schools, hotels and roads	Risk maps for population, economy, ecology and roads

2.3.3.1 Hazard assessment

For the wildfire hazard assessment elevation data was used from GISCO-EU-DEM (Copernicus, 2014). A shapefile representing the boarders of the region of interest was created by combining the four NUTS level-3 region SE110, SE121, SE122 and SE125, corresponding to the Swedish administrative regions Stockholm, Södermanland, Uppsala and Västmanland.

The shapefile was applied to the DEM-data to cut out elevation data for the region of interest.

Climate data for the assessment was downloaded from the CHELSA (CHELSA, 2025) dataset for the historical period 1991-2020.

Then land cover data was retrieved from the CORINE-2018 data set for east Sweden (Figure 2-11).

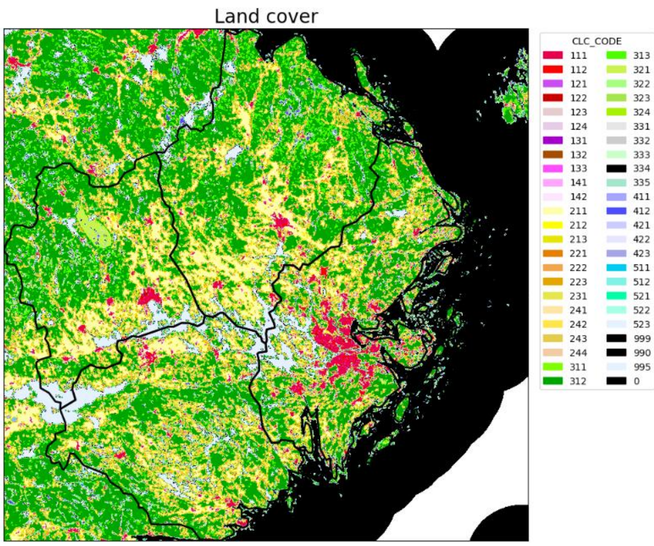

Figure 2-11 Land cover data for east Sweden from the CORINE-2018 data set.

Historical wildfire data for the period 2010-2025 was retrieved from the EFFIS (Copernicus, 2025) database. The quality of the EFFIS wildfire data for east Sweden was not very good. Only one major wildfire was detected in the dataset. In phase 2 of the CLIMAAX project wildfire data of higher quality should be used from the Swedish Meteorological and Hydrological Institute (SMHI).

As the next step of the wildfire assessment a machine learning model (ML-model) was created and trained on the historical climate and wildfire data. Also, future climate data was used from the CHELSA database for the period 2061-2080, RCP8.5 and the climate model RCA4. The susceptibility of the ML-model was investigated for the historical and future climate data and showed to much weight on the historical fire event in the north-west part of the region of interest

(Figure 2-12). The susceptibility of ML-model can hopefully be improved with better quality in the historical wildfire training data.

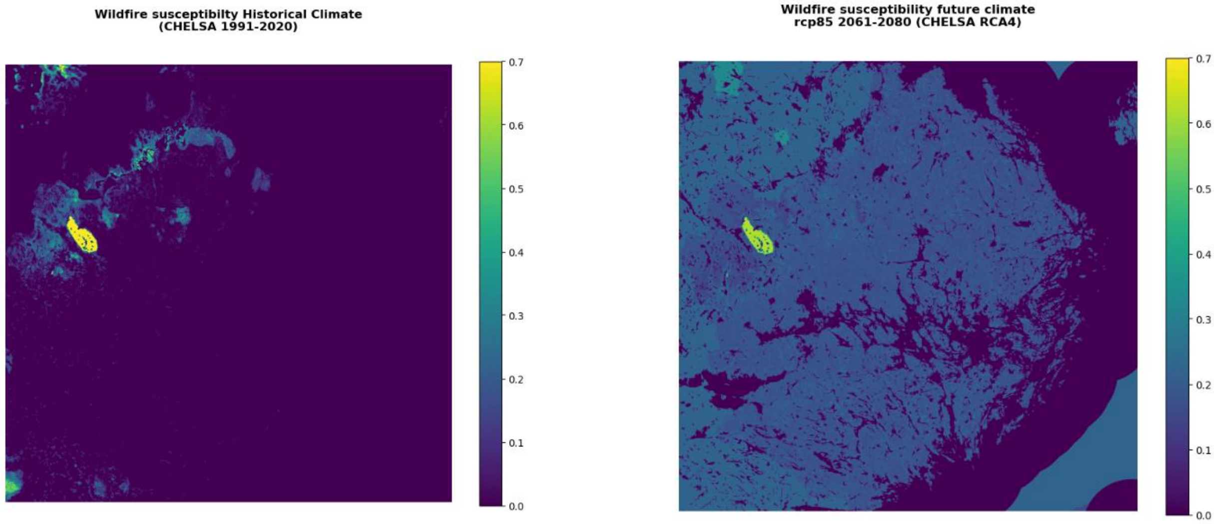

Figure 2-12 Susceptibility of the ML-model for the historical (left) and future (right) climate data.

The ML-model could now visualize the historical and future wildfire hazard for east Sweden (Figure 2-13). The historical wildfire hazard looks reasonable with lower hazard in the lower land areas closer to the inland water bodies, and higher hazard on the dry islands in the Baltic archipelago and in the inland areas with higher altitude. The future wildfire hazard projects a general large increase in hazard but does not seem very reliable with the only feature standing out being the historical fire area in the northwest part of the region of interest.

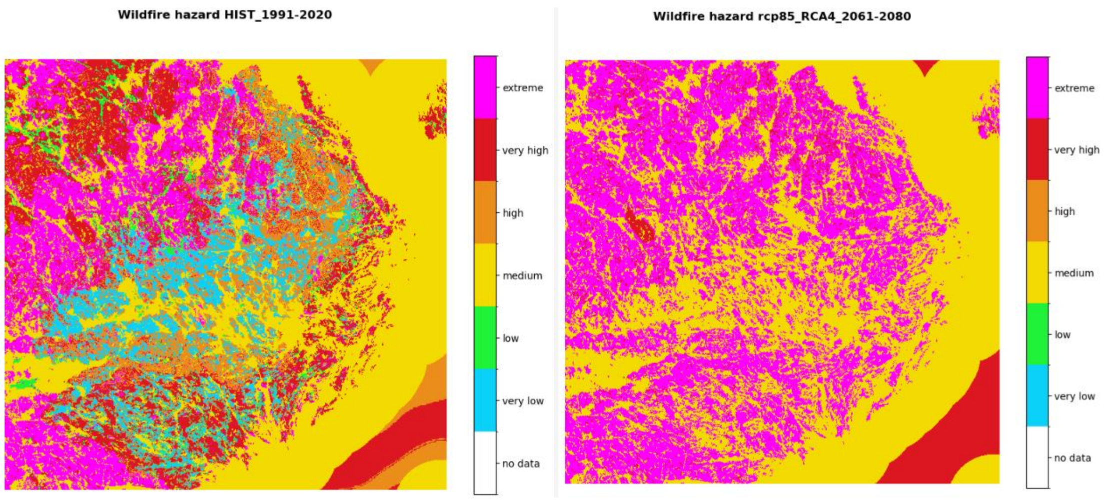

Figure 2-13 Historical (left) and future (right) wildfire hazard for east Sweden derived from the ML-model.

2.3.3.2 Risk assessment

In the wildfire risk assessment, the risk was calculated by the formula:

Risk = Hazard * Vulnerability * Exposure

The results from the hazard assessment step with vulnerability and exposure data obtained respectively from the Joint Research Centre (JRC) and OpenStreetMap were used. Vulnerability indexes were used for population, ecology and economy. Exposure data was used on hospitals, schools, hotels and roads (Figure 2-1414).

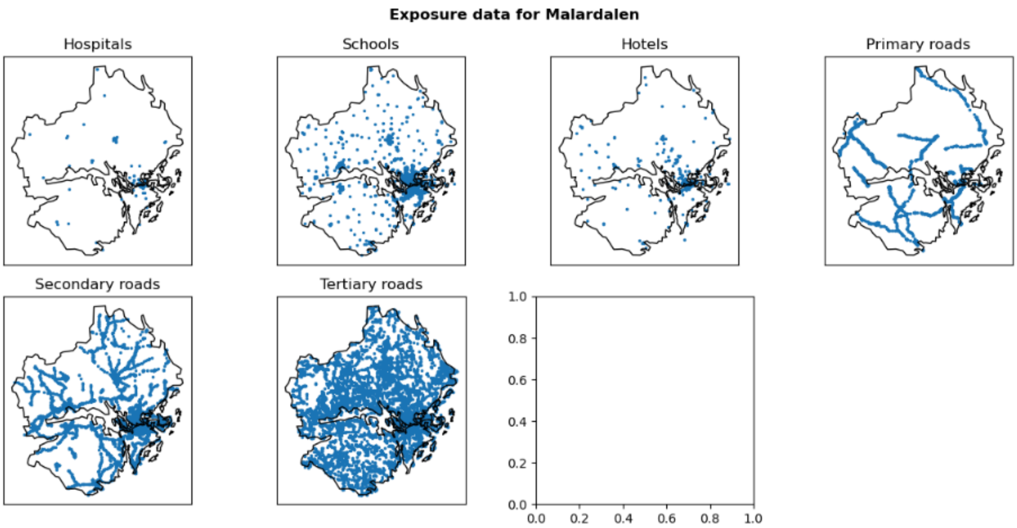

Figure 2-1414 Exposure data from Open Street map on hospitals, schools, hotels and roads. The empty subplot in the lower right corner is for shelters that was omitted from the assessment due to lack of data.

First the wildfire risk was calculated as hazard * vulnerability. The risk based on population, economy and ecology were visualized in Figure 2-15. Generally, the risk was lower in the low altitude land areas and in more urban areas with an increasing risk in the future projections for the period 2061-2080 compared to the historical period 1991-2020.

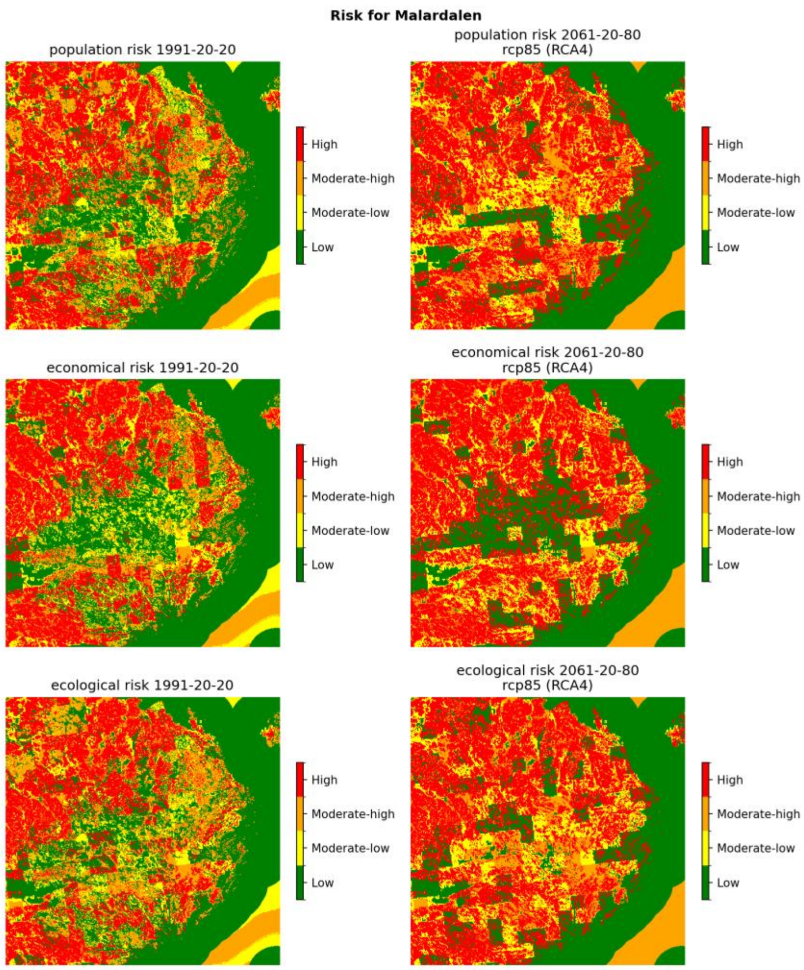

Figure 2-1515 Wildfire risk based on population, economy and ecology for east Sweden for historical (left) and future climate (right).

Then the risk was aggregated on NUTS3 level for east Sweden and plotted. For the historical period the risk was higher in the west and north parts of east Sweden and for the future period the risk was high for the whole east Sweden.

In the next step the wildfire risk was calculated as hazard * exposure. For this step the exposure data used is for roads. The vulnerability for the roads was classified in three categories, low, moderate and high.

Then the wildfire risk was calculated for the historical period 1991-2020 and for the future period 2061-2080 (Figure 2-1616). The assessment shows an increasing risk closer to the urban centres and in the future climate compared to the historical climate.

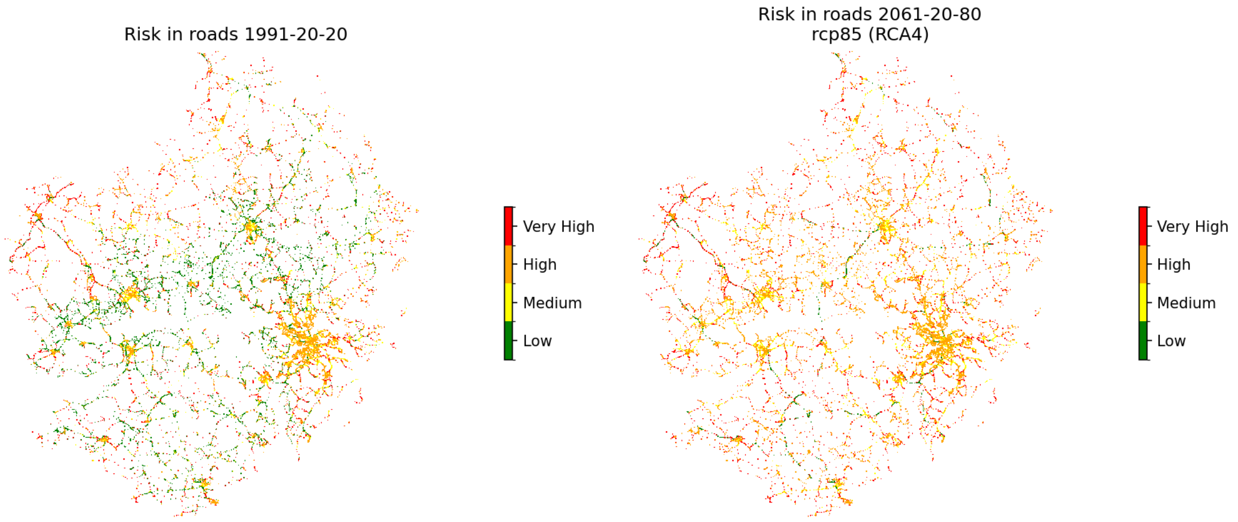

Figure 2-1616 Vulnerability Wildfire risk for the historical period 1991-2020 (left) and for the future period 2061-2080 (right).

In phase 2 of the CLIMAAX project other types of exposure data can be included in the assessment together with more future time periods, scenarios and climate models.

2.4 Preliminary Key Risk Assessment Findings

The findings from phase 1 are preliminary and will be further developed and more detailed in phase 2 of the CLIMAAX project with more local input data and comparisons between different models and scenarios.

2.4.1 Severity

For a 3-hour precipitation event with a return period of 10-years in the Mälardalen region during the future period of 2041-2070 the rain amount is projected to be around 15-30 mm. The national threshold for heavy rainfall is 50 mm per hour or 1 mm per minute, but rainfall producing 40 mm per 24 hours is perceived to be heavy. For a 24-hour event the return period for a 60 mm rain was around 50 years for the historical period. The frequency of heavy rainfall is expected to increase, which may lead to financial damage, damages to infrastructure, problems for water and sanitation and human health. Based on this analysis the severity of the risk is medium high.

For heatwaves Universal Thermal Climate Index (UTCI) days index usually occurs 1-2 times a year for the historical period of 1940-2020 with some years reaching up to 6-8 with a slight increase over time. The occurrence of heatwave days for Bålsta increase from around 5 heatwave days each year in the present climate to 10-15 days for RCP4.5 and around 25 days for RCP8.5 in the end of this century. The analyses of heatwaves show the clearest risk due to heat islands and the distribution of vulnerable citizens. The effect of heat islands may increase further depending on how the physical structures are developed. Based on this analysis the severity of the risk is high due to the large increase in frequency.

For wildfires the analysis shows an increasing risk over time. The historical wildfire hazard looks reasonable with lower hazard in the lower land areas closer to the inland water bodies, and higher hazard on the dry islands in the Baltic archipelago and in the inland areas with higher altitude. The future wildfire hazard projects a general large increase in hazard but does not seem very reliable with the only feature standing out being the historical fire area in the northwest part of the region of interest. Wildfire risk based on population, economy and ecology also show an increase over time. Based on this analysis the severity of the risk is high.

2.4.2 Urgency

The risks of heavy rainfall, heatwaves and wildfires is expected to increase with time and changing climate. Heavy rainfall and wildfires are associated with sudden events, which makes them difficult to plan for and can have major impacts on short notices. Heatwaves are somewhat easier to predict but can persist for many weeks. The urgency for all the hazards is evident, but measures for heavy rainfall and wildfires are more of a crisis-management type, whereas heatwaves are long term plans and routines. Increased resilience, knowledge and preparedness will however make us better able to handle all the hazards.

2.4.3 Capacity

The municipality has a risk management plan that briefly address climate related hazards. Focus is on civil unrest and external threats. The fire department has a high capacity to fight fires and is also involved if a flood would strike. In extreme weather conditions with long heatwaves and droughts, such as experienced in 2018, the capacity is somewhat limited. The resources may be allocated elsewhere which makes Håbo vulnerable. The awareness of the possible effects of climate change is low, and therefore the capacity to respond and act proactively is low.

2.5 Preliminary Monitoring and Evaluation

It was a challenge in the workflows to get the right input data in the right format. Especially the right geographical coverage and projection. It was also sometimes challenging to provide the correct internal pathways in the workflows to access the right datafiles. In some workflows the input data didn´t have enough resolution to enable a valuable evaluation of the results. In phase 2 of the project several model combinations and scenarios can be compared to provide a measure of the precision and reliability of the results,

The fire department informed the project that the risk analysis for wildfire would have better use with data on forest, buildings and agricultural land, rather than the road network that was used in phase 1. Flooding should be prioritized in the next phase.

In phase 2 we need to use more local detailed input data to improve the value of the results. Possibly we also need more competence on Geographical Information System (GIS) to be able to prepare the local data to work together with the workflows. The Swedish Meteorological and Hydrological Institute will be contacted to discuss possible collaboration in data collection, processing and analysing.

2.6 Work plan

Phase 2:
The sub-contractor used in phase 1 will be hired for the refinement and improvement of the risk assessment by using local data. Together with the sustainability strategist, the sub-contractor will decide which methods and which local data to use to provide an advanced risk assessment, tailormade to the municipality's special conditions. This phase will also include the expertise from the Swedish Metrological and Hydrological Institute (SMHI) to gain access to data of high quality. The close cooperation will ensure that the knowledge created in the analyses is transferred to the municipality.

The workflows that will be prioritized in phase 2 include flooding from heavy rainfall, heatwaves and wildfires in named order. Should there be time left for more workflows, drought and snow are also relevant for the municipality.

This phase will have a large element of internal and public dialogue to raise awareness, gather information and ensure the establishment of the assessment.

Phase 3:
The sub-contractor will make suggestions for adaptation measures in dialogue with the sustainability strategist. The sustainability strategist will coordinate the organization-wide analysis of which risk-managing routines need to be created, and which preventative measures need to be taken. This analysis will include internal and external stakeholders, to ensure the relevance of the adaptive measures and to raise awareness. The data, knowledge and adaptive measures will be gathered in a Climate adaptation program and plan.

3 Conclusions Phase 1- Climate risk assessment

The data analysed through the workflows show that the risk for all hazards (heavy rainfall, heatwaves and wildfire) will increase due to climate change. The result is, however, not specific enough to draw informed conclusions on which adaptive measures are needed and prioritized. The fine adjustments, local data and wider range of models that will be used in phase 2 will hopefully provide a more specific result.

Main key findings:
For a 3-hour precipitation event with a return period of 10-years in the Mälardalen region during the future period of 2041-2070 the rain amount is projected to be around 15-30 mm. For a 24-hour event the return period for a 60 mm rain was around 50 years for the historical period. The frequency of heavy rainfall is expected to increase, which may lead to financial damage, damages to infrastructure, problems for water and sanitation and human health.

For heatwaves Universal Thermal Climate Index (UTCI) days index usually occurs 1-2 times a year for the historical period of 1940-2020 with some years reaching up to 6-8 with a slight increase over time. The occurrence of heatwave days for Bålsta increase from around 5 heatwave days each year in the present climate to 10-15 days for RCP4.5 and around 25 days for RCP8.5 in the end of this century. The analyses of heatwaves show the clearest risk due to heat islands and the distribution of vulnerable citizens. The effect of heat islands may increase further depending on how the physical structures are developed.

For wildfires the analysis shows an increasing risk over time. The historical wildfire hazard looks reasonable with lower hazard in the lower land areas closer to the inland water bodies, and higher hazard on the dry islands in the Baltic archipelago and in the inland areas with higher altitude. The future wildfire hazard projects a generally large increase in hazard but does not seem very reliable with the only feature standing out being the historical fire area in the northwest part of the region of interest. Wildfire risk based on population, economy and ecology also show an increase over time. Based on this analysis the severity of the risk is high. The ML model for wildfires will probably show a varied result if data of higher quality is used. In this analysis the model gave heavy weight to a large fire in a neighbouring municipality, which was basically the only one in the dataset.

4 Progress evaluation and contribution to future phases

The results from the first deliverable are meaningful for the future of the project. The results will be used to tune the workflows and will, with the addition of local data and a variation of models, provide high quality information on future climate projections. Input from the stakeholder dialogues in phase 1 will be used to prioritize the workflows for phase 2.

Table 4-1 Overview key performance indicators

Key performance indicators phase 1	***Progress***
2 workflows successfully applied on Deliverable 1	Workflow for heavy rainfall, heatwaves and wildfire completed.
3 municipal stakeholders involved in the activities of the project	Sustainability strategist, GIS-coordinator and Water and Sanitation strategist are involved
20 external stakeholders involved in the activities of the project	2 external stakeholders participated in a dialogue meeting, 9 have subscribed to our e-mail list and 11 gave input during a public event
1 activity involving external stakeholders in the project	Meeting with external stakeholders took place on the 25th of August
2 communication actions taken to share results with your stakeholders	Results were shared by • Dialogue meeting with external stakeholders • Municipality's social media and website • Public event The results will also be shared in a public event on societal preparedness in September

Table 4-2 Overview milestones

Milestones	***Progress***
M1: Internal resources and subcontractor secured by April 2025	Contract with sub-contractor "Goodpoint AB" signed the 29th of April 2025. Internal resources secured by March.
M2: First multi risk assessment initiated by May 2025	Workflow for heavy rainfall initiated the 5th of May, followed by workflows for heatwaves and wildfire.
M3: Attend the CLIMAAX workshop held in Barcelona in June 2025	Two representatives from Håbo municipality attended the workshop
M4: First external stakeholders meeting done by August 2025	Meeting with external stakeholders took place on the 25th of August
M5: Second multi risk assessment initiated by December 2025	
M6: Second external stakeholders meeting done by January 2026	
M7: Analysis of multi risk assessment made by August 2026	
M8: Sixth external stakeholders meeting done by October 2026	
M9: Presentation of the results to policy and decision makers in our region by November 2026	

5 Supporting documentation

The outputs presented below can be found in the Zenodo repository for CAP HM with DOI **10.5281/zenodo.17020165**

Communication outputs

External communication

Public presentation

Visual outputs

Heavy rainfall

heavy_rainfall_3h_Håbo_area_precip.png

heavy_rainfall_24h_Håbo_area_precip.png

heavy_rainfall_annual_3h_balsta.png

heavy_rainfall_annual_24h_balsta.png

mean precip duration 3h event mälardalen.png

mean precip duration 24h event mälardalen.png

Projected Changes in Return Period (Frequency) for 100mm 24h Events in2041-2070.png

Projected difference in return periods for 100mm 24h events in Mälardalen 2041-2070 vs 1976-2005 OSM.png

Heatwaves

SMHI_pthbv_t_2014_2024_monthly_4326 Bålsta.png

heat risk maps Bålsta.png

Heatwave occurrence rcp 4_5 8_5 health SWE.png

Heatwave occurrence rcp 4_5 8_5 national SWE.png

heatwave risk maps Bålsta.png

Håbo heatwave rcp4_5.png

overheated areas in Håbo.png

plot_actual_evolution UTCI Håbo.png

plot_actual_evolution_tropical_nights_Håbo.png

plot_actual_stat_evolution UTCI Håbo.png

plot_anomaly_evolution_tropical_nights_Håbo.png
plot_climatology UTCI Håbo.png

plot_climatology_tropical_nights_Håbo.png

plot_historical_anomalies UTCI Håbo.png

plot_historical_anomalies_tropical_nights_Håbo.png

Wildfire

Corin land cover 2018.png

DEM-east-swe.png

Fire hazard future Chelsa 2061-2080.png

Fire hazard historical Chelsa 1991-2020.png

Fire susceptibility future Chelsa 2061-2080.png

Fire susceptibility historical Chelsa 1991-2020.png

Historical fires.png

OSM exposure data for Mälardalen.png

Region-of-interest-wildfire.png

risk1_HIST_1991-2020_rcp85_RCA4_2061-2080.png

risk1_NUTS3_HIST_1991-2020_rcp85_RCA4_2061-2080.png

risk2_roads_HIST_1991-2020_rcp85_RCA4_2061-2080.png

Vulnerability level of roads.png

Collected datasets

SMHI_pthbv_t_2014_2024_monthly_4326 Bålsta-2.csv

Main report

CLIMAAX_M6_Deliverable_CAPHM_Phase1

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